TIME MOTION ANALYSIS OF UNDER-19 RUGBY UNION PLAYERS DURING MATCH-PLAY

by

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Dissertation submitted in fulfilment of the requirements in respect of the degree

MASTERS ARTIUM IN HUMAN MOVEMENT SCIENCES

in the Department
EXERCISE AND SPORT SCIENCES
in the Faculty
SCHOOL OF ALLIED HEALTH SCIENCES
at the
UNIVERSITY OF THE FREE STATE
BLOEMFONTEIN

31 January 2020

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DECLARATION

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ACKNOWLEDGEMENTS

I wish to express my sincere thanks and appreciation to the following persons:

- First and above all I would like to thank my Saviour Jesus Christ for guiding me and making it possible to complete this journey. All the glory goes to Him.

- My wife, Wilmarie, for her support and guidance as well as encouragement to complete the dissertation.

- Dr Riaan Schoeman, for the patience and assistance and guidance to complete the dissertation.

- Prof Robert Schall, thank you for the analysis of the data. I really appreciate your input in the study.

- The Grey College First rugby team of 2019 for their participation and support of the study.

Tertius Christopher Steyn
January 2020

SUMMARY

Introduction: *Rugby is a highly intermittent sport that is characterized by many different physical demands such as walking, jogging, running and sprinting at maximal velocities. The requirements between forward and backline players differ, so do the physical and physiological demands of u/19 rugby players. Understanding the physiological demands of u/19 rugby is essential to the development of rugby coaching as well as strength and conditioning programmes in South Africa.*

Objectives: *The purpose of this study was to profile physical and physiological demands of under-19 rugby players during match-play in the 2019 rugby season, as well as to compare these demands across different positional groups. The following physical demands were recorded using global positioning system (GPS) technology for time motion analysis (TMA): total player load, total player load per metre, distance covered, total distance percentage in velocity bands 1-5, total duration in velocity bands 1-5, and the maximum velocity.*

Methods: *GPS data of the 15 player positions in rugby for u/19 first team schoolboy rugby players were collected in 11 matches, with 149 data sets. GPS data was collected by the Catapult Minimax X4 units to determine the physiological demands of on-field playing positions. The following variables were recorded: total player load, total player load per metre, distance covered, total distance percentage in velocity bands 1-5, total duration in velocity bands 1-5, and the maximum velocity.*

This study made use of a quantitative, cross-sectional research design to determine the physical demands of u/19 rugby match-play using GPS technology. Specific measuring equipment, namely tri-axial accelerometer GPS technology, was used to measure the physical activity profile of u/19 rugby players. Participants were selected using non-random sampling. The researcher had the availability of these players and therefore used convenient sampling. Furthermore, the pairwise mean differences between playing positions were estimated, together with P-values associated with the null-hypothesis of zero mean difference between the pair of playing positions in question.

Results*: The total player load (TPL) was higher in forwards than in backline players, with locks experiencing the highest TPL. The data in Table 4.1 shows that the mean TPL for all positions in under-19 rugby was 583.7 Player Load™(PL) (au). The highest mean TPL values were experienced by the positions locks (636.4 PL (au)), props (603.3 PL (au)) and lose forwards (600 PL (au)). The lowest mean TPL values were experienced by the flyhalf (541.7 PL(au)), wings (526.1 PL(au)) and fullback (556.8 PL (au)) playing positions. The mean total distance covered by all under-19 rugby players was 5733.5 m over a period of 11 matches in 2019. The fullback position covered the highest distance 6119.2 m, followed by the scrumhalf 5872.6*

m, centres 5800.3 m, flyhalf 5689.4 m and all backline positions. The forwards covered lower distances than that of backline players, except for the position of hooker 5796.7 m. Lock 5695.8 m and loose forwards 5692.1 m had similar distances. The lowest mean value for total distance was by the props covering 5584.5 m on average. This confirms that distances covered are higher in backline players. The mean maximum velocity value for all positions was 8.3 m.s^{-1}. The total duration mean value for all players showed that the most time was spent in velocity bands (VB)1-2, compared to less time spent in VB3 and the least time spent in VB4 and 5.

Conclusions: *The study revealed the differences in the player profile of u/19 rugby players participating in first team rugby at u/19 level. The findings confirm that the physical demands of forwards and backline positions differ from one another, as is true when comparing u/19 rugby to professional rugby. GPS technology can be used as a monitoring tool for player management and the findings of the study should be considered when designing conditioning programmes. Forwards and backline players have different physical demands and should be trained accordingly in u/19 rugby.*

Key words: *Time motion analysis; Under-19 rugby; Physical demands*

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Table 1: List of Abbreviations

Abbreviations	Meaning
GPS	Global Positioning System
TMA	Time Motion Analysis
TPL	Total player load
TPL per metre	Total player load per metre
TD	Total distance
Td%	Total distance percentage
td	Total duration
VB	Velocity band
MV	Maximum velocity

Table 2: Units of measurements

Unit of measurement	Meaning
G	Gravitational force
Hz	Hertz
$km.h^{-1}$	Kilometres per hour
$m.s^{-1}$	Metre per second
m	Metre
$m.min^{-1}$	Metres per minute
min	Minute
%	Percentage
s	Seconds

CHAPTER 1
INTRODUCTION AND PROBLEM STATEMENT

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

1.1 Introduction

Rugby union (rugby) is classified as a high intensity sport, that is an intermittent team sport which consists of repeated high intensity activities such as running, sprinting and tackling, interspersed with periods of walking or jogging (McLellan *et al*., 2013; Roberts *et al*., 2008). Rugby is a sport that involves physical contact where there are inherent risks (Kraak *et al*., 2017). Physical injuries and the overuse in conditioning are factors to consider, together with high fitness and physical demands of rugby that are required by all players. Coaches and players should be aware of the high physical demands placed on teams both in professional rugby and at under-19 (u/19) rugby level.

Rugby is played at different age levels. From school level to provincial and national level, and at the highest level, international rugby. The game of rugby starts at junior level, where the focus is on development of basic skills and fitness. Senior level rugby matches are played at amateur club level to professional level where players are paid to play the game. The playing pathway for young rugby players in South Africa is through the education programmes of schools where schoolboys enter junior rugby and leave school at u/19 level. Rugby players may continue playing rugby at further education and training institutions after school, either at provincial or club level where they will enter the senior level phase of rugby union.

Rugby consists of both physical contact through tackling and collisions as well as physical fitness demands that are characterised by running activities such as quick changes between walking, jogging, running and high intensity sprinting (Tee *et al*., 2016). Rugby is also characterised by set running and passing moves, ball kicking, scrummaging, mauling and line-out play. Rugby is both an offensive and defensive game, consisting of attacking with ball in-hand as well defensive skills players competing for the ball possession. These demands require a high level of fitness from each position. The requirements for u/19 rugby players in South Africa still need to be documented and analysed as little research exists at this level of rugby in South Africa.

Differences in physical performance have been noted between forwards and backs. With regards to the positional demands for rugby, players are divided into tight forwards (props and locks), loose forwards (hookers, flanks and eighth men), and scrum half, inside backs (fly half, and centres) and outside backs (wings and fullbacks) (Tee *et al*., 2016). The physical demands and intensities for forwards and backs differ greatly from one another. Forwards and backs playing position requirements are inherently different due to the physical activity requirements of each position (Tee et *al*., 2016).

Backs are involved in more high intensity activities such as running and sprinting compared to that of forwards who show more static efforts involving wrestling, rucking and mauling phases of the game (Reardon *et al*., 2017). Forward play involves more line-out, scrumming and rucking and mauling phases, where backline play involves more high intensity running and sprinting activities, both followed by longer periods of recovery time (Reardon *et al*., 2017). The physical demands of professional rugby have widely been studied and published on international and provincial level. There seems to be little studies done at u/19 rugby level in South Africa for both forwards and backline players.

Rugby has benefitted from time motion analysis (TMA), with first video based, and then global positioning system (GPS) technology (Tee *et al*., 2016). Many advancements in match analysis, equipment technology and player training have contributed to changes associated with the introduction of professionalism at rugby union level (Quarrie *et al*., 2007). The use of GPS technology to analyse time motion analysis of rugby players at professional level is widely recognised and studied. Many studies have been complete on the physical demands of rugby union matches at professional level.

Every sport has its own specific physiological demands that coaches and conditioning specialists need to consider when preparing for competitions (Thomas *et al*., 2016). Performance analysis through TMA using GPS technology can be used to quantify the performance of rugby players and is one way of determining the physical workload of rugby matches. The recent enhancements of GPS technology have allowed strength and conditioning specialists to assess and measure the physiological workload of rugby teams, for all players partaking in rugby matches.

The Catapult minimax X4 system is a GPS tool that is used to monitor athletes' performance through TMA and performs extremely well during short sprints and changes of direction (Petersen *et al*., 2009). Today GPS technology includes a three-dimensional data collection, which acts as a function of the tri-axial accelerometer device that enables data collection at high frequency during match-play which in turn provides a measure of movement quality (Fish *et al*., 2014). The Catapult Minimax X4 is widely used to assess and measure the physical demands of professional rugby. There have been major changes in the physical demands of rugby union over the past three decades (Schoeman *et al*., 2017). The results of TMA not only provide important information on the physical game demands, but also highlight the differences between players in various positions (Davidson *et al*., 2008). Analysing u/19 rugby

through TMA and GPS technology can be beneficial when used in the development of professional rugby programmes.

This study serves to provide information on the physical and physiological demands placed on u/19 rugby players during match-play. The planning of training programmes according to the knowledge gained through the use of GPS technology for TMA will provide a measure of the physical demands and running characteristics placed on u/19 rugby players during match-play. Understanding the physical demands of u/19 rugby players will be important for all coaches and conditioning specialists when setting up conditioning programmes for u/19 rugby teams.

1.2 Problem statement

The level of physical performance on u/19 rugby has improved in the past decade. The increased physical and physiological demands placed on u/19 rugby players can be seen on the rugby matches played compared to past seasons. The improvements in running demands placed on u/19 elite level rugby occurs at first team schoolboy rugby and in u/19 provincial rugby in South Africa. The standard of play has also dramatically improved in the last decade, playing rugby as competitively as in professional rugby.

The constant striving to win and be the number one position of elite rugby schools of South African ranking has led to the game becoming far more professional than in the past. The competitiveness between schoolboy rugby has led to the developments of professional rugby coaching as well as improved strength and conditioning programmes at u/19 rugby level. The research question is to investigate if these coaching and conditioning programmes are based on the true physical and physiological demands experienced by u/19 rugby players during match-play.

The improvements in rugby coaching and strength and condition programmes at u/19 rugby level has many benefits for u/19 rugby players. These benefits may include prevention of injury through limiting overuse in conditioning to avoid injury risk to and to improve fitness of rugby players that will help players to reach their best physical performance when competing in u/19 rugby. Little research has been done at u/19 school and provincial level rugby with regards to assessing TMA using recent tri-axial accelerometer GPS technology to determine the physical and running demands of rugby players during match-play (Cummins *et al*., 2013). In order to develop specific conditioning programmes and recovery strategies for rugby players, it is essential to have a thorough understanding of the game and the unique physical and running

demands of different playing positions (Venter *et al*., 2011). The use of portable GPS devices has become a popular and convenient method to quantify movement patterns and physical and running demands of rugby using GPS technology (Akenhead *et al*., 2014).

There have been no studies done on TMA using GPS technology on u/19 schoolboy rugby level in South Africa. In order to provide specific information for rugby-related conditioning and coaching programmes, GPS technology will be used to assess the rugby positional player profile of the physical and running demands (Cummins *et al*., 2013). Thus, investigation into the physiological and physical demands of u/19 rugby players needs to be assessed. The true physical demands for each rugby position must be profiled in order to set up coaching and conditioning programmes for u/19 rugby. Various components of coaching and conditioning programs could be aided in the investigation of player activity profile.

1.3 Aim of the study

The aim of this study is to profile the physical and physiological demands of u/19 first team schoolboy rugby players during match-play. The secondary aim is to compare these demands across different positional groups in u/19 rugby. The physical demands of u/19 rugby will be determined through the TMA analysis by use of tri-axial accelerometer GPS technology to discover the true physical demands placed on rugby players in their different positional groups and provide the physical profiles for elite u/19 rugby players during first team school rugby competitions. GPS recording will be used to research various physical demands of players taking part in the study.

Physical profile components will include: total player load, total player load per metre, distance covered, total distance percentage in velocity bands 1-5, total duration in velocity bands 1-5, and the maximum velocity. The results will be examined for benefits to coaches and strength and conditioning specialists to implement fitness and conditioning programs and protocols that will aid and serve as a guideline for coaching staff when setting up conditioning programs at elite u/19 first team school level rugby to improve physical performance of u/19 rugby players during competitions.

1.4 Objectives of the study

The specific objectives of the study are:

1. To determine the total player load (Load TM.min -1 (au)) of the different positional groups in u/19 rugby players during match play, as well as to measure the total player load per metre for the different u/19 rugby positional groups during match-play,

2. To determine the total distance covered (m) of u/19 rugby players and to investigate the difference between the different positions,

    2.1. Standing: No locomotor activity (0 - 0.1 m.s-1),
    2.2. Walking: Either strolling locomotor activity in a forwards, backwards, or sideways direction (0.2 – 1.7 m.s-1),
    2.3. Jogging: Slow, non-purposeful running with no obvious acceleration (1.8 – 3.6 m.s-1),
    2.4. Running: A fast running action with distinct elongated strides, effort and purpose (3.7 – 5.3 m.s-1),
    2.5. Sprinting: Running with maximum effort or at maximum speed. (>5.4 m.s-1),

3. To determine the percentage of total distance covered during the above-mentioned player movement patterns by u/19 rugby players and to investigate the difference between the different positions,

4. To determine the total time spent in the different velocity bands for all playing position during match play, measured as a percentage of the total playing time,

5. To determine the maximum velocities measured in m.s-1 of all player positions during match play,

6. To compare the positional groups of “forwards” and “backs”.

1.5 Motivation for the study

The need to access the physical demands and physiological demands of the game of rugby at u/19 level will aid and assist both rugby coaches and sports conditioning specialist when setting up training programmes and conditioning sessions for u/19 rugby players. Gaining knowledge of the physiological demands of athletes during competition is a fundamental requirement needed in order to enable conditioning coaches to construct a sport-specific conditioning programme (Miller *et al.,* 2017).

The lack of knowledge of the physiological demands and demands of running placed on u/19 rugby during match-play makes it difficult to truly access the training demands needed for elite performance for rugby players to be competitive in match-play. Gaining knowledge of these demands through use of a measuring tool by using TMA by GPS technology gives coaches and players an insight to the true physical demands needed to compete at the highest level of u/19 rugby during match-play, in order to construct relevant training programmes.

It can be deemed necessary to determine the physical demands of each position at under-19 rugby level as well to determine the physical demands and differences of positional groups “forwards” and “backs”. It is then important to take note that the positional demands of each position may differ, and that following the same conditioning programmes for all players may not be effective as the requirements for each position are different. One must also take into consideration that the positional and physical demands of each position is being developed and improved every year, changing as the game is evolving. Therefore, establishing player specific physical demands may give insight to both coaches, conditioning specialists and players at under-19 level. The gap of research data on junior rugby needs to be addressed (Read *et al*., 2017).

The specific physical demands, namely the total player load, total player load per metre, distance covered, total distance percentage in velocity bands 1-5, total duration in velocity bands 1-5, and the maximum velocity need to be assessed when analysing an u/19 rugby match through TMA using GPS technology. In order to provide specific information for rugby-related conditioning and coaching programs, GPS will be used to assess player physical profile activity (Cummins *et al*., 2013). These aspects will be of great benefit to all partaking in u/19 rugby in South Africa.

1.6 Structure of the dissertation

The structure of the dissertation consists of the following chapters:

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

Chapter Two: Literature review: This chapter will review previous literature which is relevant to the research aims of the dissertation as stated in Section 1.2. The literature review includes the physiological demands and a need for understanding the physical performance of under-19 rugby. TMA is used to analyse and access these physical performance and physiological demands by use of GPS technology. The literature discusses sound methodological approaches to access the demands on under-19 rugby. The chapter is included herewith in accordance with the guidelines of the Free State University.

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

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

Chapter Five: Discussion of the results of the study.

Chapter Six: Conclusion, limitations and future research.

Chapter Seven: Reflection on the research project.

CHAPTER 2

LITERATURE REVIEW

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

2.1 Introduction

The purpose of this chapter is to provide knowledge and insight of the physiological demands and the physical demands of rugby union (rugby), through accessing the demands of running placed on rugby players at under-19 (u/19) level during match-play. It aims to give a detailed description of the game of rugby and to discover the true physical demands of u/19 rugby and to access the physical demands on the different positional requirements. The secondary aim is to compare the physical demands between the positional groups of forwards and backs at u/19 level. The rapid changes and improvements of the physical performance of rugby players in the past decades (Schoeman *et al*., 2017), the changing nature of the game needs to be assessed at u/19 level.

Time motion analysis (TMA) through the use of global positioning system (GPS) technology has become a common tool in quantifying the physical demands of rugby players across the globe. Access to the knowledge and understanding the physical demands placed on u/19 rugby players at school level should be beneficial to all involved in the rugby world.

Professional rugby union matches are played over two 40-minute halves separated by a break not exceeding 10 minutes. There are no interruptions, except in the event of an injury (Duthie *et al*., 2003). U/19 rugby union matches are played over two halves, each consisting of 35-minutes with a 5-minute half-time break. According to Reardon *et al*., (2017) rugby is a dynamic contact sport, which is played by two teams of 15 players where each team is comprised of eight forwards and seven backs. The playing positions in rugby union are separated in to ‘forwards’ and ‘backs’. The positional groups in rugby are classified into two groups where forwards are numbered 1 to 8 while backs are numbers 9 to 15.

The game of rugby continues to grow and develop internationally and in South Africa, especially after the recent 2019 Rugby World Cup, where South Africa were crowned as winners. The game of rugby continuously gains popularity all over the world and especially in the United States (Hume *et al.*, 2017). Both men’s and women’s clubs have been established at several colleges and universities (Dietzen *et al*., 1999).

Rugby is played at different age levels in South Africa. Rugby players may enter the game at primary school level, following through to secondary school where they will play in first teams across the country at competing at u/19 level. From here rugby takes on a more serious and professional level as schoolboys either go to club level or university where they can play in the Varsity Cup competitions against other university teams in South Africa. U/19 rugby

players from schools are often given contracts to play for clubs or provincial teams. The step up from u/19 level to senior level and professional rugby requires highest performance, this can only be assessed through looking at the physical demands of rugby players at u/19 level.

The use of GPS technology to analyse TMA rugby players at professional level is widely recognised and studied. Many studies have been complete on the physical demands of rugby union matches at professional level. TMA uses GPS technology to track and analyse the physical performance of rugby players and their positions. Research shows that GPS technology can accurately quantify the physical demand placed on rugby players. Although there are numerous studies done at professional level, little seems to have been done at u/19 level.

The use of GPS technology to assess the physical demands of rugby players for TMA is widely recognised and is a common tool that researchers use to quantify the demands placed on rugby players. To quantify the high intensity demands of rugby, many studies have done that show that TMA through GPS technology advancements has made it possible to quantify the physical demands for professional rugby. Rugby has benefitted from time motion analysis, with first video based, and then global positioning system (GPS) technology (Tee *et al*., 2016). Together with many advancements in match analysis, and equipment technology and player training have contributed to changes associated with the introduction of professionalism at rugby union level (Quarrie *et al*., 2007). Rugby became a professional sport in 1995. Since then the game has become more explosive in the physical aspects of speed and power and high levels of intensity dominate the game.

The aim of this chapter is to summarise the literature pertaining to the physiological demands of rugby with reference to discovering the physical demands required for different player positions during match-play. It will firstly provide an overview of the nature of rugby, the different playing positions and the physical demands of the game. Secondly, the major aspects of the physical demands placed on different positions in rugby. And thirdly, it will provide literature that is relevant and sound methodological approaches when using GPS technology through the Catapult Mini max 4 system to analyse the physical demands of under-19 rugby players during match-play.

2.2 The game of rugby

2.2.1 Background and overview of rugby union

The game of rugby was first developed and played in Scotland in the town of Rugby where the sport acquired its name. The laws date back to 1845, but rugby union only became professional in 1995 and was played at amateur level previously. Scotland has a long rugby union tradition with the first international match played between Scotland and England in 1871 (Macleod, 2016). The game has vastly developed from the 1800s and in 1995 it changed from an amateur sport to a professional sport. Since then the sport of rugby has vastly developed and has changed vastly in the past three decades (Schoeman *et al*., 2017).

2.2.2 South African rugby perspectives

The sport of rugby is widely played and enjoyed throughout South Africa in all age levels. Developments in the physical condition of rugby has made the game more competitive. After participating in the 1995 Rugby World cup, South Africa is a country that is united through sport (Pillay *et al.,* 2012). The physical demands placed on South African rugby players greatly changed and developed since 1995. With the developments in TMA analysis through GPS technology, the physiological demands of rugby players in South Africa have easily been acquired and monitored. Schoeman et al. (2019) noted that rugby has changed in the past three decades.

Changes in coaching and conditioning practices have made the game of rugby more competitive in all phases, from amateur to senior rugby, moving to the development of players at junior level and u/19 level. Today schools employ conditioning coaches to manage rugby teams from as early as u/14 to u/19 level. Strength and conditioning specialists design specific conditioning programmes for developing young rugby players. Yet the question of what the true physical demands of junior rugby are, are yet to be discovered. U/19 is the last phase in junior rugby and serves as a gateway to professional senior rugby. The physical demands of u/19 rugby players are most important for strength and conditioning specialist and rugby coaches as they should know and understand the demands placed on rugby players competing during match-play for the purpose of setting up conditioning and coaching programs that are relevant to the demands of match play.

South Africa participated in the Rugby World Cup at professional level since 1995, winning it for the first time in South African history. Since then the national team has, has played in every world cup and won it a total of three times, the last being in 2019 in Japan. The same can be

said for the Rugby World Cup of 2019 that united South Africans again though supporting the national team to victory. Rugby is not only important for the enjoyment and physical development of spectators, players, coaches and conditioning specialists but can also to unite a nation.

2.2.3 Participation levels of rugby: age

Rugby is also played from junior level in primary school to senior level at provincial, national and at the highest level, namely international rugby union for the national side, are called the Springbuck rugby team. The game of rugby is played at both senior and junior levels across South Africa. Senior level rugby matches are played at amateur and professional levels, whereas junior rugby level is played at school level in primary and secondary school. Teams in high school already start with conditioning at u/14 level, through to u/19 level, which is the top of school rugby in South Africa.

The playing pathway for young rugby union players in South Africa is through the education programmes of schools where schoolboys enter junior rugby and leave school at u/19 level. Rugby players may continue playing rugby union at further education and training institutions after school, either at provincial or club level where they will enter in the senior level phase of rugby union.

Since then the professional era of rugby there have been many advancements in coaching, training and conditioning programmes. The sport is practiced by rugby players from a young age, developing ball skills and the physical components needed for the game. U/19 rugby is seen as the top of junior rugby and a gateway that then enters to professional rugby, at club level, provincial level and u/21 level. The highest team that a junior rugby player can play is u/19 first team rugby moving to provincial and national colours for rugby at u/19 level.

According to Miller *et al*., (2017) one essential requirement for designing a sport specific training programme is the understanding and knowledge of the physical demands placed on the players during match play. Having knowledge of the physiological demands and understanding what the physical demands of u/19 rugby requirements for matches in South Africa are can be beneficial to all involved in the u/19 rugby setup at both school and provincial level. Quantifying the physical demands of rugby through TMA using GPS technology provides important information on the game demands and involves the differences between various positions played (Davidson *et al*., 2008). This information will aid all players and coaches involved in u/19 rugby in South Africa.

2.2.4 Playing positions in rugby

According to Reardon *et al*. (2017) rugby is a dynamic contact sport, which is played by two teams of 15 players where each team is comprised of eight forwards and seven backs. The playing positions in rugby are distinguished between forwards and backline players. Differences in physical performance have been noted between forwards and backline players.

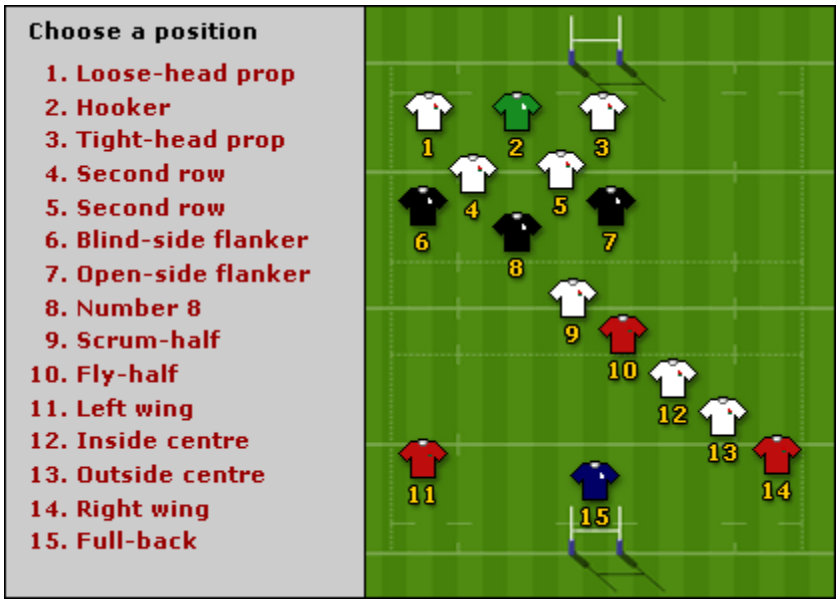

Figure 1: Different rugby positions
(http://schools.cbe.ab.ca/b857/athletics/Rugby/rugby_basics.html)

Positional demands for rugby union, players are divided into tight forwards (props and locks), loose forwards (hookers, flanks and eighth men), and scrumhalves, inside backs (flyhalves, and centres) and outside backs (wings and fullbacks) (Tee *et al*., 2016). The physical demands and intensities for forwards and backs differ greatly from one another. Forward and backline playing position requirements are inherently different due to the physical activity requirements of each position (Tee *et al.,* 2016). Backs are involved in more high intensity activities such as running and sprinting compared to that of forwards who show more static efforts involving wrestling, rucking and mauling phases of the game (Reardon *et al*., 2017). Forward play involves more, line-out, scrumming and rucking and mauling phases, where backline players are more involved in high intensity running and sprinting activities, both followed by longer periods of recovery time (Reardon *et al.,* 2017).

2.2.5 The playing surface

The dimensions of a rugby pitch must be between 94m-100m in length and 68m-70m in width, the in-goal area must be between 6m-22m in length. The dimension of the goal posts, situated centrally on the goal line are 5.6m between the posts, the top edge of the cross bar is at a height of 3m and the posts must have a minimum height of 3.4m above the cross bar (Macleod, 2016).

2.2.6 Playing time and duration of matches

Professional rugby union matches are played over two 40-minute halves separated by a halftime break not exceeding 10 minutes. Thus, players are involved in physical activities for periods of 80mins on-field active playing time. There are no interruptions, except in the event of an injury (Duthie *et al*., 2003). U/19 level rugby union matches are played over two halves, each consisting of 35-minutes with a 5-minute half-time break. Thus, players competed against one another for a period of 70 minutes actively involved in match play.

2.2.7 Laws of rugby

The laws of rugby can be found under the World Rugby website laws.worldrugby.org where all players participating in rugby must abide in the rules of the game (World Rugby 2015). Although the current study analysed the possible effect of law changes on the general profile of international rugby, it is acknowledged that the law changes are not the only contributors to the changes in the general match profile.

Kraak *et al*., (2017), analysed the general match profile of rugby players between 2007 and 2013, noting that the law amends are fundamental to the game of rugby and other sports for a variety of reasons (Kraak *et al*., 2014). The results showed that there was a significant decrease in scrums, (d=1.03), line-outs (d=0.65) and penalty kicks (d=0.46), the study also showed in number of passes and (d=0.42), ball carries (d=1.22) and tackles attempted (d=0.65) and penalty kicks (d=0.98). This study implies that the law of the game does affect the physical nature of the game of rugby. The general match profile has decrease and moved to a game with a decrease in the number of set pieces and kicks to increase in the number of ball carries and tackles (Kraak *et al.*, 2017).

2.2.8 The role of GPS technology for TMA in rugby union

2.2.8.1 Time motion analysis

Global positioning systems (GPS) testing systems have been widely used and recognised when assessing the time motion analysis of senior rugby players to determine the physical activities for each position in senior rugby union matches (Cummins *et al*., 2013). The recent development in GPS technology proves to be beneficial for quantifying these physical demands of rugby.

Time motion analysis was originally measured by means of game video recordings, measuring the physical game demands of rugby union through video analysis (Cunniffe *et al.,* 2009). With recent developments in GPS technology the reliability and viability has made it possible to measure physical performance in team and individual sports more accurately (Gabbett *et al*., 2012). This information is used to establish specific player activity profiles that describes the on-field real time physical performance of athletes and sports teams today (Cummins *et al.,* 2013). Sports scientists, rugby coaches as well as strength and conditioning staff have found it easy to make use of these developments for developments in conditioning and coaching programs by tracking and measuring physical performance for both real time game analysis and on-field training sessions (Cunniffe *et al.,* 2009). Cummins *et al.* (2013) agrees that “the use of GPS technology to measure physical performance also provides the opportunity to measure player position, velocity and different movement patterns which provide important information for both sports scientists and conditioning coaches for many team sports”.

The importance of TMA analysis for under-19 rugby may prove beneficial to knowing the demands that are placed on both forwards and backs. This is based on the research of game analysis through application of TMA using GPS technology. Knowledge of the physical demands through TMA and GPS testing may prove beneficial when setting up the activity profile and training programmes at under-19 level. There have been very few studies done and none to date in South Africa, that focus on the performance and physical demands of rugby at under-19 level. The physical demands of under-19 rugby union using TMA may prove beneficial to discover and identify the true demands for preparation training activities as well as the game demands during matches that are placed on junior rugby players to perform. The physical activity for rugby union matches at schoolboy still needs to be determined and assessed.

2.2.8.2 Global Positioning Systems (GPS)

Global Positioning Systems (GPS) is a navigation system consisting of 27 operational satellites orbiting around the earth. The United States Department of Defence for navigation purposes (Larsson, 2003) originally developed GPS. Although it was originally used in tactical military operations, GPS technology was introduced to team sports in 1997 (Cummins *et al.*, 2013), using satellite-based navigation technology to track individual performance. GPS has become widely recognised for measuring physical performance and has been implemented in many team sports such as rugby, hockey and many other sports (Cummins *et al.,* 2013).

GPS technology has recently become an effective tool to measure time motion analysis in team sports (Akenhead *et al*., 2014). GPS technology now provides sports scientists with the knowledge to gain information on high and low intensities of distance covered during a competition. According to Gabbett *et al*. (2012) the reliability and validity of individual sprint and change of direction speed activities were relatively poor and that: “recent evidence that the tri-axial accelerometers and gyroscopes embedded in the micro-technology units offered a valid and reliable means to automatically detect the collisions and tackles that occur in rugby league”. Cummins *et al*. (2013) also noted that the improved monitoring and understanding of physiological performance demands through use of GPS technology by analysing the positional and movement patterns of on-field performance will optimise and aid training. There is an abundance of research on the reliability and validity of GPS measurements of the on-field movement to determine the activity profile.

In the past, commercially available GPS systems were used to track athlete performance, automatically determined by the Doppler shift method. This method describes the changes in measurement according to the changes in satellite signal frequency and the movement of the receiver unit, thus determining the speed and distance of the athlete (Larsson, 2003). New developments now provide opportunities to gain valuable data on game demands in team sports like rugby union, through objectively measuring the distance and speed through tri-axial accelerometer as well as Doppler shift method. Through the investigation of game demands, the training methods can be improved by knowledge of positional requirements, physiological loads and energy demands of the sport (Cunniffe *et al*., 2009). This can be beneficial to rugby union at u/19 level when measuring and determining the physical activity profile for players.

The recent developments of GPS technology and tri-axial accelerometer used in determining the activity profile has made it possible for the measuring of not only distance covered and speed, but especially physical loads and work-rates of players in team sports such as rugby

(Cummins *et al*., 2013). The development in portable GPS units has allowed for wider use and application in analysing and understanding the spatial context of physical activity (Cummins *et al*., 2013). To access sporting performance and measure the physical demands of a rugby player's performance, sport scientist and coaches have widely turned to knowledge and assessment of time motion analysis, using these forms of GPS technology improvements. Sports scientists are now able to develop activity player profiles for on-field physical performance and evaluate the training loads through improved portable tracking devices (Cummins *et al*., 2013).

The portable GPS units permit qualitative measurement through improved GPS triangulation methods and accelerometer software which enables the capture of information on work rate and physical loads (Cummins *et al*., 2013). The development of portable GPS technology further allows for measurement of body load (G-force), acceleration/deceleration, changes in direction, contact with ground (foot strikes and falls), measurements of speed and impact zones (Cummins *et al*., 2013). GPS technology is therefore relevant to rugby competitions as rugby is an intermittent high-intensity sport, in which activities that call for maximal strength and power are interspersed with periods of lower intensity aerobic activity and rest (Cunniffe *et al.,* 2009).

The improvements of GPS tri-axial accelerometer technology have proved beneficial to aid both sport scientists and rugby coaches when setting up and developing coaching and conditioning programmes at senior level. This acquired data form u/19 level rugby will bring knowledge and serve as a guide for conditioning purposes as it will be able to serve as the base for entering the next phase of rugby, namely, the transition from school level to u/21 and professional rugby. Special attention is needed when setting up the activity profile at u/19 level is thus most important and will be beneficial to both sports scientists, conditioning and rugby coaches at u/19 and senior level rugby. Applying this sport specific information from GPS tracking, using time motion analysis at u/19 level will aid the rugby players' development in both physical performance conditioning and rugby coaching. Thus, the importance for setting up of an activity profile for first class under-19 rugby using latest GPS technology.

Data analysis and monitoring of the physical demands of junior players are of utmost importance and must be determined for South African junior rugby player development. The gap of research data on junior rugby needs to be addressed (Read *et al*., 2017). Although studies attempted to shed more light on the demands of u/19 rugby union, the sample sizes were small and only limited number of matches and players analysed. There is little evidence

of entire team analysis over a season in junior rugby union by use of GPS and TMA in South Africa, of which the physical demands need to be assessed.

U/19 rugby is termed as the last phase of junior rugby where high school teams compete at first team level. This phase of rugby at u/19 level is the preparation phase that serves as a gate way to reaching the beginning of senior level rugby. The benefits for analysing and testing the physical performance of u/19 rugby, may be beneficial to the both players and coaches as well as sports scientist when setting up conditioning programmes for u/19 rugby players.

2.3 The physiological demands of rugby

The physical demands of rugby are assessed using GPS technology for TMA. The following objectives are used to classify the physical demands placed on rugby players during match-play. McLaren *et al.* (2016) noted that the physical activities of senior rugby union match play is characterised by short, intermittent bouts of high intensity activity over a period of 80 minutes.

Physical activities are comprised of tackling, running and sprinting, changes in direction, acceleration and deceleration under high velocities, static exertions and repeated-high intensity efforts, which are followed by longer periods of lower intensities and rest (McLaren *et al.,* 2016). Read *et al.* (2017) concurs that senior rugby union is a highly intermittent contact sport and that the physiological characteristics of senior rugby union players comprises of many different physical activities. Bursts of maximal strength and power are predominant to the game of rugby union (Cunniffe *et al*., 2009). The physical demands are both high-and-low intensity.

The improvements in research acknowledge that TMA is becoming a popular method to quantify the physical demands various team sports (Gabbet *et al.,* 2008). Not having a proper understanding of the physiological demands of sport could lead to problems when setting up position specific programs (Chandler *et al*., 2014). Thus, the need for investigation into the physical demands of under-19 rugby.

The physical demands of rugby can be characterised into many aspects, a few of which must be noted:

- Total Player Load (au)
- Total player load per metre,

- Total distances covered
- Total distance percentages
- Total duration during velocity bands
- Maximum velocities of rugby players

2.3.1 Player Load

2.3.1.1 Total player load

Total player load (TPL) is described as the measure of physical activity in all 3 planes of movement. McLellan *et al*. (2011) reported that player movement patterns and activity profiles (external loads) can be used in addition to tactical information and physiological responses (internal load) to characterize competitive match play. To determine physical activity of players, the Catapult Minimax X4 accelerometer unit measures accelerations in the frontal-, sagittal- and transverse axes of movement to determine a variable called player load (PL) (Gabbett *et al*., 2012). Chandler *et al.* (2014) described the PL as a measure of physical activity by measuring the accumulation of accelerations in all 3 planes of movement (frontal, sagittal and transverse (Chandler *et al*., 2014). Chandler *et al*. (2014) described total player load (PlayerLoad^{TM}·m^{-1}(au)) and total player load per metre (PlayerLoad^{TM}·m^{-1}(au)). Recent improvements in wearable devices by Catapult Minimax X4 make it capable to measure and quantify the variables necessary for determining TPL in rugby players and provides new opportunities for research in sport (Montgomery *et al.,* 2010).

The formula to calculate Player load (PL) (Boyed *et al.,* 2011):

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

where

Ac1 = Forward acceleration

Ac2 = Sideways acceleration

Ac3 = Vertical acceleration

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

For the purpose of the study of u/19 rugby players, TPL and TPL per metre will be investigated. TPL measuring the physical demands in 3 different planes. TPL per metre measure the physical demands placed on players per metre of the distance covered during match-play.

2.3.2 Total distance during match-play

Distance covered during rugby match-play

The total distance covered during match-play is measured in metres (m). Distance covered by athletes during competitions is one of the most studied variables in sports science (Belka *et al.,* 2014). Various sports present different physical demands, one of which should be monitored in rugby is the total distance covered during a match for both forwards and backline players in u/19-rugby. Cunningham *et al*. (2016) noted that u/19 rugby league players covered distances of 5 – 6 km during match-play, while Twist *et al*. (2014) noted u/19 rugby players covering distances 5 – 8km.

Deutsch *et al*. (1998) analysed six players during four u/19 matches at different levels of play. Although backs had a lower overall exertion based on heart rate, they covered the greatest distance, with props and locks covering 4400 ± 398 m, back row 4080 ± 363 m, inside backs 5530 ± 337 m and outside backs 5750 ± 405 m. This is less than the average total distance of 6953 m reported by Cunniffe *et al*. (2009), who also used GPS technology with two participants (mean age 25 ± 3.6 years) from an elite rugby union club team during one game. A breakdown of this distance showed that 2800m was spent standing and walking, 1900m jogging, 700m cruising, 990m striding, 320m high intensity running, and 420m sprinting. It should, however, be noted that Cunniffe *et al.* (2009) analysed 83 minutes from the game, while Deutsch *et al.* (1998) analysed 60 minutes each from five games. Venter *et al.* (2011) showed that u/19 players covered on average a total distance of 4469.95 ± 292.25 m during a game. The front row forwards covered the greatest total distance (4672.00 ± 215 m), followed by outside backs (4597.93 ± 210.18m), inside backs (4307.78 ± 214m), and then back row forwards (4302.1 ± 529.82 m). Distances measured by Venter *et al*. (2011) are similar to that of Deutsch *et al.* (1998) and can be due to time played by u/19 rugby competitions are less than senior level as reported by Cuniffe *et al.* (2009)

Comparisons between under-20, under-18 academy and schoolboy distances covered in rugby match-play showed that in a recent study done in TMA with the use of GPS technology, the physical demands on match-play for under-20 England international-standard rugby players were measured. The results showed that greater total distances were covered in backs than in forwards (6230 ± 800 vs. 5370 ± 830 m, effect size [ES] = 1.10) and that these results on total distance covered were comparable with that covered in senior rugby (Cunningham *et*

al., 2016; Reardon *et al*., 2015). Read *et al*., (2017) showed physical demands of under-18 schoolboy players to that of academy players.

The following differences were noted (Read *et al*., 2017). They also noted that the total distances covered by under-18 and academy rugby players differed. The results of the showed that forwards from the academy (5461 ± 360 m) and school (4881 ± 388 m) were likely, and very likely to cover less total distance than academy (5639 ± 368 m) and school backs (5260 ± 441 m) (Read *et al*., 2017).

Read *et al*. (2017), also noted that distances covered by school players are substantially less than previously reported for international U20 players (forwards: 5370 ± 830, ES = 0.98; backs: 6230 ± 800 m, ES = 1.94). Total distance covered in Pro 12 rugby players (forwards: 5639 ± 762, ES = 1.52; backs: 6172 ± 767 m, ES = 1.82) (Cunningham *et al*., 2016; Reardon *et* al., 2015).

Academy backs also have less total distance than older age-grade players (Cunningham *et al*., 2016) and one study shows that senior players (Reardon *et al*., 2015), whereas the forwards are similar to data reported in these studies. Read *et al*. (2017) also noted that the differences represent comparable patterns from previous studies (Austin *et al*., 2011; Quarrie *et al*., 2013) that have suggested searches for open space by backs and the subsequent repositioning in the field explain these findings (Cahill *et al*., 2013; Read *et al*., 2017).

The Catapult Minimax X4 was used to determine the distances covered during u/19 rugby matches. The Minimax X4 has a coefficient of variation of <2% that proves the reliability of the accelerometer using (Boyd *et al.,* 2011). The distance covered by rugby players during match-play shows the distances may vary in different age levels of the game. The duration of match-play needs to be considered as well when analysing the distance covered as senior games consists of 80-minute games and those of u/19 rugby consists of 70-minutes. Thus, differences between senior level and u/19 players should be recognised and when evaluating total distance covered. Further research in South Africa needs to be done on the demands placed on u/19 rugby players.

2.3.3 Total distance velocity bands and duration of rugby matches

Total distance can be classified in the different velocity bands measured by the Catapult Minimax 4X for TMA. These velocity bands can be classified into 5 velocity bands. Table 2.1 shows different movement patterns according to Otago (1983), Steele *et al*. (1992) and

Davidson *et al*. (2008). Table 2.2 shows the classifications for movement patterns by Fox *et al*. (2013) and Yong *et al*. (2015).

Table 2.1 Classification of movement patterns according to Otago (1983), Steele *et al*. (1992) and Davidson *et al*. (2008)

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

Table 2.2 Classification of movement patterns according to Fox *et al*. (2013) and Yong *et al*. (2015)

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

Speed zone and time spent in speed zone

High-intensity bursts comprise of running, sprinting, tackling, mauling, and continuous change of direction under high velocities. These physical activities also include longer low-intensities activities that consist of jogging and walking during the game (Duthie *et al.,* 2003). McLean (1992) determined that when the ball was in open play, the average running pace of players central to the action ranged from 5 to 8m/s.

Durations of time spent in velocity bands 1-5

Venter *et al.* (2011) reported maximum speeds reached did not differ significantly between the groups of players. Outside backs reached speeds of 33.10 ± 0.79 km.h1, followed by inside backs (27.97 ± 1.42 km.h), back row forwards (26.01 ± 2.32 km.h), and then the front row

forwards (23.01 ± 2.03 km.h). The highest average player running speeds over the games were 4.69 ± 0.38 km.h (outside backs) and the lowest were 4.30 ± 0.47 km. h (back row forwards). According to Austin *et al*. (2011) the durations of the most intense repeated high intensity exercise bouts for each position ranged from 53s to 165s and the minimum recovery periods between repeated high intensity exercise bouts ranged from 25s for the back row forwards to 64s for the front row forwards.

The most intense periods of activity are likely to last as long as 120s and as little as 25s recovery time may separate consecutive repeated high intensity exercise bouts. Venter *et al*. (2011) reported that the time spent walking in under 19 match play for the outside backs are on average 36 min 12 s ± 2 min 21s (60.34 ± 3.92%), which is significantly more ($p<0.05$) than the 25 min 15 s ± 5 min 59s (42.1 ± 9.99%) of the front row forwards. Venter *et al*. (2011) also showed that props and locks spent on average more time jogging (15 min 40 s ± 2 min 16 s or 26.11 ± 3.77%), compared to outside backs (9 min 22 s ± 1 min 23 s or 15.6 ± 2.3%). Outside backs spent more time sprinting (39.96 ± 4.48 s or 1.11 ± 1.18%) than inside backs (25.92 ± 10.8 s or 0.72 ± 0.30%), the front row forwards (17.28 ± 8.28 s or 0.48 ± 0.23%), and back row forwards (17.28 ± 4.68s or 0.48 ± 0.13%) (Venter *et al.,* 2011). Within elite under-19 colts' rugby, forwards spent a larger percentage of time standing still (46%) compared with the backs (39%) and covered a shorter distance in all gait movements except jogging (Deutsch *et al*., 1998). Numerous studies done on the game demands of rugby union, results show that players can travel up to 7500 m of which 25% were performed at moderate and high speed running (Cahill *et al*., 2013; Coughlan *et al*., 2011; Lacome *et al*., 2013; Roberts *et al*., 2008).

When considering the duration of rugby matches, differences can be seen between forwards and backline players for the 5 different velocity bands. Backline player spent more time walking compared to that of forwards, while forwards had higher percentages standing still, although higher velocities showed that backline players sprinted and covered the highest distances in maximum velocities for velocity band 4 and 5. Props spent highest time jogging. One must acknowledge that the physical demands required of each player in each velocity band differs from position to position. Cummins *et al*. (2013) highlighted that backline players have more running-based activity than forwards who perform more static efforts of wrestling, rucking, scrummaging and mauling phases. These phases are often difficult to evaluate with GPS technology. Coughlan *et al*. (2003) agreed that back and forward players had difference, backs covered greater distances during matches with high intensity running and maximal speed running than that of forwards. The risk of injury and decrease performance can occur if excessive training and competitive demands are not followed by proper recovery periods (Brooks *et al*., 2008; Coutts *et al*., 20007; Owen *et al*., 2015; Gabbet and Jenkins, 2011).

Players must be aware of these inherent risks of overtraining and competitiveness. The results of under-19 rugby will provide standards of total distance during match-play.

2.3.4 The application of GPS technology and TMA for rugby

The role of GPS technology is widely recognised as an instrument to quantify the physical demands of rugby players. Understanding the role of GPS in rugby, we must look at the performance analysis of rugby players, our aim will be to improve our understanding of the game behaviour that we may improve the future performance of rugby players and teams (McGarry, 2009). When looking at the selection of rugby players by coaches, technical and physical performance analysis is important, but performance methods can also play a role in team selection; hence they need to be accurate and well understood by those using them to inform decisions (Macleod, 2016).

Many aspects of the physical demands can be discussed, but for the study purposes of under-19 rugby these five physical demands were measured. GPS technology can serve in many roles of rugby union.

Firstly, to assess the true physical demands of rugby players during match play as well as in training sessions. This will provide a norm or standard of the physical demands that are required in different positions in rugby union. Especially between forwards and backline players. This is relevant for under-19 level.

Secondly, to monitor the performance of rugby players and teams. These seem to kept secret in the rugby community (Macleod. 2016). Rugby coaches and conditioning specialist now have a monitoring tool that can provide match-day information and on-field training data that can help manage and assess player performance. Prevent overtraining and reduce injury.

Thirdly, for players to be able to see and understand their physical performance levels. To provide feedback that is player specific of match day performance and training sessions. Rugby players will be able to motivate and manage themselves better.

Fourth, to provide the international research community with information and data of current developments in TMA of rugby and sport in general. This knowledge can used to strength the standard of playing by all rugby players and teams across the world.

Fifth, to strengthen the knowledge of players, coaches, and conditioning specialist on the physical demands of platers performance standards in rugby.

Lastly, to provide performance standards and guidelines for rugby players of all ages.

2.4 Summary

Numerous studies have been done to quantify the physical demands of rugby match-play through TMA using GPS technology. The study aims to provide an overview of under-19 rugby and the application of TMA using GPS technology to access the true physical demands and demands of running during match-play. Aspects such as the player load, total distance covered and the total duration as well as the maximum velocity for all rugby positions are to be accounted for. The comparison between positional groups can also be accessed when comparing the physical demands of forwards and backs. Knowledge and information gathered by GPS technology is easily accessible and understandable for players, coaches and conditioning specialists who seek to improve and perform at the highest levels. The everchanging game of rugby must continually be assessed to inform all involved of the latest developments in rugby. TMA using GPS technology can be used successfully when used in the right hands of coaches and sports scientists that try to stay up to date with the latest research on the physical demands of rugby players.

CHAPTER 3
RESEARCH METHODOLOGY

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

3.1 Introduction

The aim of the study was to investigate the physical demands of under-19 rugby through use of tri-axial accelerometer GPS technology and to create a physical activity profile of under-19 rugby. This was done through analysis of the physical activity of the under-19 first rugby team of Grey College of 2019. GPS technology, Catapult Minimax X4 was used to research the various physical aspects of the under-19 rugby players that participated in the study during the 2019 rugby season. The researcher measured the following physical components which include: total player load, total player load per metre, distance covered, total distance percentage in velocity bands 1-5, total duration in velocity bands 1-5, and the maximum velocity.

The results were examined for the benefit of under-19 rugby players, rugby coaching staff and strength and conditioning specialists to aid and serve them with data and information that acts as a guidance when setting up coaching and conditioning programmes and protocols for under-19 rugby. The purpose of this section was to gain a deeper understanding into the study design and methodology used to provide answers to the research question. The research included the process of analysis, collection and reflection of data to gain beneficial and relevant information from participants and to set up a physical profile for coaching and conditioning of elite under-19 rugby players.

3.2. Research design

McCusker *et al.* (2015) define the process of research as the “systematic and rigorous process of enquiry which aims to describe phenomena and to develop and test explanatory concepts and theories”. This research process contributes to the scientific knowledge with regards to the research topic (McCusker *et al*., 2015).

3.2.1. Study design

This study made use of a quantitative, cross-sectional research design to determine the movement patterns of u/19 rugby match play using GPS technology. The specific measuring equipment, namely tri-axial accelerometer GPS technology from Catapult X4, were used to measure the physical activity profile of u/19 rugby players at a well-known school in Bloemfontein. The participants were selected using non-random sampling method. This means that participants are selected according to the criteria that the researcher has planned prior to the study.

The movement patterns were analysed to determine the physical demands placed on the u/19 rugby players and to gain information on the physical profile for u/19 rugby players. These under-19 players were included from the first rugby team of Grey College which competed at under-19 level across South Africa in different interschools competitions in 2019. The following variables were noted: total player load, total player load per metre, distance covered, total distance percentage in velocity bands 1-5, total duration in velocity bands 1-5, and the maximum velocity during rugby matches of the 2019 rugby season.

3.3. Population and Sampling Participants

The target population for this study were the under-19 rugby players from Grey College's first rugby team of 2019. These participants form a specified population. The study maked use convenience sampling method. Convenience sampling can be described as "a cohort of subjects that happen to be in the right place at the right time" (Polit *et al*., 1993). The researcher has the availability of these specific players and are therefore known as convenient sampling method. Twenty-three players were selected from the under-19 first rugby team of Grey College.

The first rugby team participated in the under-19 first rugby team inter-schools matches that were played across South Africa. A total of 23 participants took part in the study in the 2019 rugby season of which reserves where eight reserves and fifteen on-field players provided data for the study. Matches were played by a 15-man side, with eight reserves on the bench of which only seven was allowed to be used as replacement. These reserves served as replacements for injured players or team tactics where some on-field players were substituted and replaced by reserves.

The researcher was responsible for setting up the Catapult Minimax X4 system. The researcher received basic training from the research supervisor to set up and collect the GPS pods system, where the data was then taken back to the supervisor to be downloaded onto a personal laptop of the UFS where the data was then analysed according to the primary aims of the study and to be kept safe after recording the performances of u/19 rugby players.

The data of the specific 15-man positions were calculated after the end of the match. The specific on-field position and specific replacement reserve data were calculated together to obtain an accurate player profile for the on-field 15-man side to reflect the true demands of each on-field playing position.

A total of 11 matches were used to calculate the player profiles. With the on-field player positions numbered 1-15. Each position was calculated using the GPS technology by wearing a Catapult player vest and Catapult X4 GPS unit capturing the on-field physical demands of under-19 rugby players starting at the beginning of the match and ending at the last whistle of the match. Although the first rugby team played 17 rugby matches during the season, only 13 rugby matches were recorded of which 2 matches were used as trial warm-up matches. The data from the 2 trial matches were not considered as the playing time for the warm up matches differed from that of the real full time matches. The researcher was able to monitor the physical demands of each player position for 11 full rugby matches which captured the data through the Catapult Minimax X4 GPS system for TMA during the full 2019 rugby season.

Permission was obtained through the following permission letters: permission from the headmaster of the school (Appendix B3), the coaching director and head coach of the first rugby team (Appendix B1), together with permission from the Free State Department of Education (Appendix B2). Participants also attended an information session which described the procedure, purpose of the study and the protocol of the research prior to participation of the study (Appendix A1). The information session was presented to participants in a classroom setting prior to the commencement of practice as arranged with the coaching staff. Participants were asked to sign an informed consent form (Appendix A2) or assent form (if under 18) form (Appendix A3) prior to participating and wearing the GPS technology tracking device. Parents of participants that were under the age of 18, but had been chosen to play for the Grey College first rugby team that participated at under-19 level, were required to sign a consent form (Appendix A2) so that their son would be allowed to participate in the study. All personal details of participants were kept confidential. All procedures were submitted to the Department of Exercise and Sport Sciences and the Health Sciences Research Ethics Committee of the University of the Free State.

3.3.1. Inclusion criteria

1. The players must be included in the following under-19 teams: Grey College first rugby team playing at under-19 level selected by the school coaching staff.
2. The players must be healthy and free of illness or any disease that may affect his performance or put the participant`s health at risk.
3. All participants must be under the age of 19 years old.
4. The players must be able and willing to give consent (in English).

3.3.2. Exclusion criteria

1. Players who do not adhere to inclusion criteria.
2. Players who have played a game prior to the match, on the same day, and play as a reserve will be excluded from the study. These players may be fatigued and may have lower activity levels. This may skew the data.

3.3.3. Withdrawal of study participants

If any player decides to withdraw, they may do so without any consequences. If a player might sustain an injury (not being able to play for the rest of season) or be unable to participate due to poor health or sickness, the researcher will withdraw the participant from the study. All participants were given written consent prior to use of GPS technology.

3.4. Data collection

3.4.1. Time Motion Measurements

The collection of data was uploaded after every match onto a personal laptop using GPS technology. Participants that played for the under-19 rugby team from which the data was analysed. The data was collected from the rugby matches played in the 2019 rugby season. Players had to wear the GPS units in a padded protected harness that is positioned between the scapulae in the upper thoracic spine area. GPS units were worn underneath the players' rugby jerseys (Cahill *et al*., 2012).

The researcher (sport scientist) was responsible for fitting and supplying the GPS units before the game, which were fitted 15 minutes before the warm up, approximately 60 minutes before the match commenced. Warm up data was collected and separated from that of the match data for analysis of the real time physical activity profile for competition. GPS units were switched off after a player has finished the match or left the field due to injury or substitution or for whatever reason specified by the team management. The match data was then downloaded on to the researcher's personal computer where further analysis could be carried out using the GPS technology software provided by the manufacturer. Players were divided into forwards and backs. Players were further specified according to their position according to the 15-man game of rugby union. Forwards are specified as: two props (tight head prop and loose head prop), hooker, locks, two flanks (open side and blind side flankers) and the 8th

man. Backs are specified as: scrumhalf, fly half, inside centre, outside centre, left and right-wing and fullback (McLellan *et al.,* 2013). These positions can be numbered as one to fifteen according to the team's positional demands (Cahill *et al*., 2012). Data analysis for the physical activity profile of the under-19 rugby players measured the following variables: total player load, total player load per metre, total distance covered, total distance percentages, maximum velocity experienced during the interschool's rugby matches.

To determine the total distance covered (m) of u/19 rugby players and to investigate the difference between the different positions the following velocity bands were used:

- Velocity band 1: Standing: No locomotor activity (0 - 0.1 m.s-1),
- Velocity band 2: Walking: Either strolling locomotor activity in a forwards, backwards, or sideways direction (0.2 – 1.7 m.s-1),
- Velocity band 3: Jogging: Slow, non-purposeful running with no obvious acceleration (1.8 – 3.6 m.s-1),
- Velocity band 4: Running: A fast running action with distinct elongated strides, effort and purpose (3.7 – 5.3 m.s-1),
- Velocity band 5: Sprinting: Running with maximum effort or at maximum speed. (>5.4 m.s-1),

3.5. Equipment

The tri-axial accelerometer GPS technology that was used to measure physical activity is the Catapult Minimax X4 GPS units provided by the manufacturer. The device measurement is 19x50x88 mm with a weight of 67g. The tri-axial accelerometer GPS data is recorded at 10 Hz with accelerometer and gyroscope data at 100 Hz each. The GPS unit has a battery life of approximately 6 hours and is waterproof. According to Jennings *et al*. (2014) the tri-axial accelerometer GPS technology provides the best reliability and validity results when working with units that use 10Hz to 15 Hz. Previous studies show that 1Hz to 5Hz provide a greater error analysis that is not as accurate as that of 10Hz (Jennings *et al.*, 2010). Further research has shown that this implies that the higher the speed of the participant partaking in physical activity, the greater the error for high intensity activities (Jennings *et al.*, 2010). Thus, the best results can be achieved through using 10Hz to 15Hz Catapult units for most accurate reliability and validity in GPS tracking studies (Johnston *et al*., 2013).

Cummins *et al.* (2013) also report that in terms of reliability and validity in GPS devices: "that when comparing devices of 1-Hz, 5-Hz and 10-Hz, the 10-Hz (the speed of capturing data)

provides greater validity in measuring speed and distance". Cummins *et al*. (2013) stated that GPS devices are manufactured with 1-, 5-, and 10-Hz sampling rates (the speed at which the unit gathers data). The literature suggests that GPS with a higher frequency rate provides greater validity for measurement of distance. When comparing the precision of distance acquisition between a 1- and a 5-Hz GPS, the standard error of a standing start 10-m sprint was 32.4 and 30.9 %, respectively. By contrast, a 10-Hz GPS demonstrated a 10.9 % standard error over a 15-m sprint (Cummins *et al*., 2013). Thus, suggesting that GPS devices with 10-Hz prove to provide greater reliability and validity for measuring a player's physical performance.

The researcher was responsible for the set up and collection of the Catapult Minimax X4 system, where GPS units were distributed and switched on 15-minutes before the game. After the match the GPS units were collected after the match. The time of the match was recorded and used accurately to access the match-play time for every match. The substitution times were recorded and used when players had to be replaced. These replacement recordings were used to calculate the real on-field physicals demands of the rugby positions 1-15. The data from the GPS units was stored on the personal laptop of the UFS specifically used for the Catapult Minimax X4 system. The researcher scrutinized the data by making sure that all GPS units and that the GPS data used was calculate according to the correct time of each match start and end times, as well as considering the half time. Each player positions playing time was accurately analysed for TMA. The GPS data was kept safe on the personal laptop of the UFS Department of Sport Science under supervision of the researchers supervisor.

3.6. Pilot study

Firstly, the pilot study was a dress rehearsal that the researcher used before the actual research investigation to determine any flaws in the measuring procedure. Secondly, it identified unclear or ambiguous formulated items and thirdly, it provided opportunity for the researchers and assistants to notice non-verbal behaviour on part of the participants (De Vos *et al*., 2005). The study used two pre-season matches played by Grey College. The information session and the consent procedure were applied to main study. The pilot study helped to identify any possible problems in the proposed method of conducting the study. The researcher collected the data and downloaded it to a personal computer using GPS software where the data was analysed from the pre-season matches. Matches from the pilot study were not included in the final dataset as these were only warm up matches and not part of the competitions. The playing time of these pre-season matches were different to the competition and could therefore not be used.

3.7. Statistical Analysis

Descriptive Statistics

Descriptive statistics for each activity variable are provided for each of the different players in these 11 rugby matches, separately by playing position, and overall. Note that the sampling unit was a player game, so that the summarized data was not independent: There are repeated observations for the same player (in different games), and repeated observations for the same game (from different players). For this reason, a standard deviation is not reported in the descriptive statistics.

Statistical comparison of playing positions

The various activity variables were analysed using a two-way analysis of variance (ANOVA) model with playing position and match as fixed effects. Based on this ANOVA model, the mean values (of the activity variable) for each playing position were estimated. Furthermore, the pairwise mean differences between playing positions were estimated, together with the P-values associated with the null-hypothesis of zero mean difference between the pair of playing positions in question.

The partial ω^2-statistic (SAS, 2017) is reported as an effect size measure for the effect of playing position. As a rule of thumb, the square root of the ω^2-statistic can be compared to the available rules of thumb for the interpretation of the correlation coefficient (Schober, Boer and Schwarte, 2018). The analysis was carried out using SAS procedure GLM (SAS, 2017).

The data from the GPS units were analysed through the GPS software provided by the manufacturer and be stored in a cloud-based folder. The analysis was largely descriptive and be conducted by a biostatistician. Descriptive statistics (mean, minimum, Q1, median, Q3, maximum) will be calculated for the physical activity profile variables: total player load, total player load per metre, total distance covered, total distance percentages, total duration and maximum velocity, both for the overall study sample, separately by team, and separately by playing position. Based on a linear mixed model, the mean values (of the variable) for each playing position will be estimated, together with their standard errors. Furthermore, the pairwise mean differences between playing positions will be estimated, together with 95% confidence intervals (CIs) for the mean differences and P-values associated with the null-hypothesis of zero mean difference between the pair of playing positions in question.

The analysis was carried out using SAS procedure MIXED (SAS, 2016). The values are represented in boxplots to show possible variations between different player positions (such as forwards and backs).

3.8. Implementation of findings

The physical activity profile assessed the various physical sporting components which include total player load, total player load per metre, total distance covered, total distance percentages, total duration and maximum velocity. The results were examined for benefits to coaching staff as well as the strength and conditioning specialists to aid and serve as a guideline when setting up these fitness and conditioning programs and protocols for under-19 rugby.

Furthermore, better understanding of the demands of rugby union imposed on players is needed for developing specific training and recovery plans and minimizing the risk of injury (McLellan *et al*., 2013). This research will assisted the under-19 team rugby coaches and conditioning staff to develop new training and conditioning programs that are specifically relevant to the demands of under-19 rugby. Benefits of the study may include information for injury prevention, analysis on movement patterns and work to rest ratios. Studies done on (TMA) through the use of GPS prove to be useful in gathering information that will be beneficial to both sports scientist and coaching staff for under-19 teams. Data will enable further studies when comparing TMA results to other age groups.

3.9. Ethical aspects

Participants received a written information document (Appendix A.1) and attended an information session outlining the procedure and purpose of the research. Players were asked to sign an informed consent before the study commenced (Appendix A.2) or assent form (if under the age of 18) prior to participating and wearing the GPS technology tracking device. Parents of participants that were under the age of 18 years but had been selected to play for the Grey College first team participating at under-19 level, were required to sign a consent form so that their son was allowed to participate in the study. The study was voluntary, and players did not receive any financial compensation for their participation. Participants had the right to withdraw from the study at any time. Participants were informed beforehand that the results of the study will be published. Every effort was made to keep the players personal information confidential and under all circumstances. Data was stored on a password

protected laptop. Data was available for the duration of the study until all statistical analysis was completed. Data was deleted from used laptop after the study.

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

- The Health Sciences Research Ethics committee of the of the University of the Free State;
- The Department of Exercise and Sport Sciences at the University of the Free State
- Director of rugby and Head coach of the Grey College First rugby team (Appendix B.1)
- Free State Department of Education (Appendix B.2)
- Headmaster of Grey College Secondary School (Appendix B.3)
- Minor Assent Form (Appendix A.3)

The research proposal was submitted to the Health Sciences Research Ethics committee of the University of the Free State for approval prior to commencement of the study.

CHAPTER 4
RESULTS

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

4.1. Introduction

The purpose of this chapter to present the results of the study that were obtained using the GPS technology for TMA. The physical and physiological demands of under-19 schoolboy rugby players were monitored using the Catapult Minimax X4 system. The study took place in Bloemfontein, where the teamed played and travelled across South Africa competing in inter-schools matches. The under-19 first rugby team of the school played 17 inter-schools matches, of which 11 were successfully monitored. The primary analysis objective was to provide data on the movement patterns to obtain information on physical and physiological demands and positional differences in u/19 rugby. The physical demands measured were total player load, total player load per metre, distance covered, total distance percentage in velocity bands 1-5, total duration in velocity bands 1-5, and the maximum velocity. The positional groups of forwards and backs were compared to assess the differences between the difference in playing positions with respect to the data from the movement patterns of u/19 rugby players.

The study made use of tables and boxplots to illustrate the data obtained in the study. Tables are used to present the descriptive statistics of the results. Boxplots are used to provide a graphic illustration of the distributed data that indicates the range of the data that is between the first and third quartile of the data, meaning that the central 50% of the data is visible. The difference between the first and the third quartile is known as the inter-quartile range (IQR). The most extreme point of the data that is less than or equal to 1.5 times of the IQ is indicated by the whiskers drawn from the box. Values higher or lower than 1.5 times the IQR are is played by a “+” or a “o” sign. The interpretation and discussion will be discussed in chapter 5.

4.2 Demographic information of participants

4.2.1 The number of rugby matches and player positions analysed

The study took place across South Africa, where the first team had to travel to compete in 11 different interschools matches during the 2019 rugby season. The first team competes yearly against the various tops schools in South Africa where they play interschools rugby matches that are comprised of a first and second half, each half time being 35-minutes with a 5-minute interval half-time. The under-19 first rugby team of the school played 17 interschools matches in the 2019 season, of which 11 matches were possible to successfully be monitored with the Catapult Minimax X4 GPS system for TMA.

The under-19 rugby team consists of a 15-man squad who are active on-field positions and are involved during match-play. There are eight replacement positions which may be used accordingly, either due to game tactics or injuries sustained by on-filed players. The calculations for the 15-man player profile positions included all replacement substitutions. Detailed activity (GPS) data for the 15 player positions was provided while monitoring 11 under-19 rugby matches for TMA in the 2019 rugby season.

The primary analysis objective was to provide detailed data on the different player profiles for the various playing position, and to assess the differences between the playing positions with respect to the activity data. The physiological demands of the players positions are classified as 1-15 (n+15).

For display and analysis purposes the 15 playing positions in a rugby team were grouped as follows: Props: No 1 and 3; Hooker: No 2; Lock: No 4 and 5; Loose forwards: No 6, 7 and 8; Scrumhalf: No 9; Flyhalf: No 10; Centre: No 12 and 13; Wing: No 11 and 14; and Fullback: No 15.

The specific objectives of the study are:

1. To determine the total player load (Load TM.min -1 (au)) of u/19 rugby players as well as the player load of the different positions during match play,
2. To determine the total distance covered in metres (m) of u/19 rugby players and to investigate the difference between the different positions,

2.1. Standing: No locomotor activity (0 - 0.1 m.s-1),

2.2. Walking: Either strolling locomotor activity in a forwards, backwards, or sideways direction (0.2 – 1.7 m.s-1),

2.3. Jogging: Slow, non-purposeful running with no obvious acceleration (1.8 – 3.6 m.s-1),

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

2.5. Sprinting: Running with maximum effort or at maximum speed. (>5.4 m.s-1),

3. To investigate the percentage of total distance covered during the above-mentioned player movement patterns by u/19 rugby players and to investigate the difference between the different positions.

4.3. Results of under-19 rugby during match-play

4.3.1. Total Player load

The results for TMA through GPS technology using the Catapult Mini X4 system provided the following data in terms of total player load (TPL) and total player load per metre. This data was completed in the 2019 rugby season and consisted of 11 rugby matches. The descriptive statics for TPL for all the player positions are shown in Table 4.1 TPL.

The results are further displayed by the boxplots and provide information on the distribution of data for total player load (au) and total distance (m) according to Figure 4.1. In the Table 4.2 the pair-wise p-values provide statistical comparisons of all player positions for the Player Load™(PL) (au). Further statistical comparisons can be seen in Table 4.3 which shows the mean values and effect size for all player position in terms of the TPL. From these statistical comparisons it is possible to find playing positions with possible similarities or differences in under-19 rugby.

Table 4.1. Total Player Load [Player Load™ (au)]: Descriptive statistics

	Position name									
	Centre	**Flyhalf**	**Fullback**	**Hooker**	**Lock**	**Loose forward**	**Prop**	**Scrum half**	**Wing**	**All**
N	22	11	10	8	19	32	19	10	20	151
Mean	573.7	541.7	556.8	593.4	636.4	600	603.3	596.5	526.1	583.7
Min	423.3	430	422.7	429.8	439.7	424.9	377.5	434	412	377.5
Median	583.2	542	552.7	595.6	652.8	603.8	586.7	597.4	505.4	582.8
Max	690.4	636.7	691.7	693.6	877.4	797.9	832.1	834.5	752.9	877.4

The data in Table 4.1 shows that the mean TPL for all positions in under-19 rugby was 583.7 Player Load™(PL) (au). The highest mean TPL values were experienced by the positions lock (636.4 PL (au)), props (603.3 PL (au)) and lose forwards (600 PL (au)). The lowest mean TPL values were experienced by the flyhalf (541.7 PL(au)), wings (526.1 PL(au)) and fullback (556.8 PL (au)) playing positions.

The maximum TPL experienced a player in a single match over a period of 11 matches was the locks (877.4 Player Load™ (au)), followed by the scrum half (834.5 PL(au)) and props (832.1 PL(au)). The minimum total player load was experienced by props (377.5 PL(au)) followed by wings (412 PL (au)).

The results of the data for under-19 rugby players' TPL were also illustrated using boxplots. Figure 4.1 indicates that the highest TPL was experienced by playing position for locks, loose

forwards and props. This correlates with the mean values in Table 4.1. Furthermore, the player positions wings and flyhalf experienced the least TPL in 11 rugby matches. Lock and loose forwards experienced the similar TPL followed by the hooker. The centres experienced the highest TPL of all backline positions.

The player position locks have the highest median followed by loose forwards, scrumhalf, hooker and props. This data illustrates that forward players experience the highest TPL when compared to backline players in under-19 rugby. Interestingly, centres experienced the highest TPL of the backline players.

When comparing the inter-quartile ranges (IQR) for TPL, the player position props had a greater IQR range, meaning that there was greater variation in the central 50% of the data. Therefore, the TPL experienced by props varied more from match to match. The second largest IQR range was by the fullback. The centres and the wings had the smallest IQR, meaning that these players experienced the least variation between matches for TPL by a playing position.

When comparing the upper quartile values for TPL, the props showed the highest value, followed by locks, loose forwards and hookers. The wings and the flyhalf player positions have the smallest lower quartile values. This supports the previous finding that forwards have a higher TPL than that of backline players for u/19 rugby.

The relation between the TPL and Total Distance (TD) covered, it is notable that the fullback experience the highest TD covered by a player, although the median for TPL was the third lowest by players. This will correlate with a lower TPL per metre as illustrated in Figure 4.2 and Table 4.4.

Table 4.2 provides the pairwise p-values for TPL. These values provide information on the statistical comparisons for the different player position in u/19 rugby. When comparing positions, the locks and wings showed the significant differences between positions in TPL ($p<0.001$). The locks had the highest TPL compared to other positions, and wings had the lowest TPL.

Similarities can be noted between the locks and the props, followed by the loose forwards and the hooker. These players are all forward playing positions. The similarities between backline players can be noted for the scrumhalf, centres and were followed by the loose forwards. Flyhalf and fullback had lower TPL with the least TPL experienced by wings.

Table 4.3 displays the mean values and effect size of the statistical comparisons between positions. The TPL values confirm that lock had the highest TPL. Similarities can be found between props, loose forwards and scrum half. There is no significant difference between scrum half and hookers. Similar TPL were experienced for the centres, fullback and flyhalf. The effect size (ω=0.31) was relatively small in comparing different player positions.

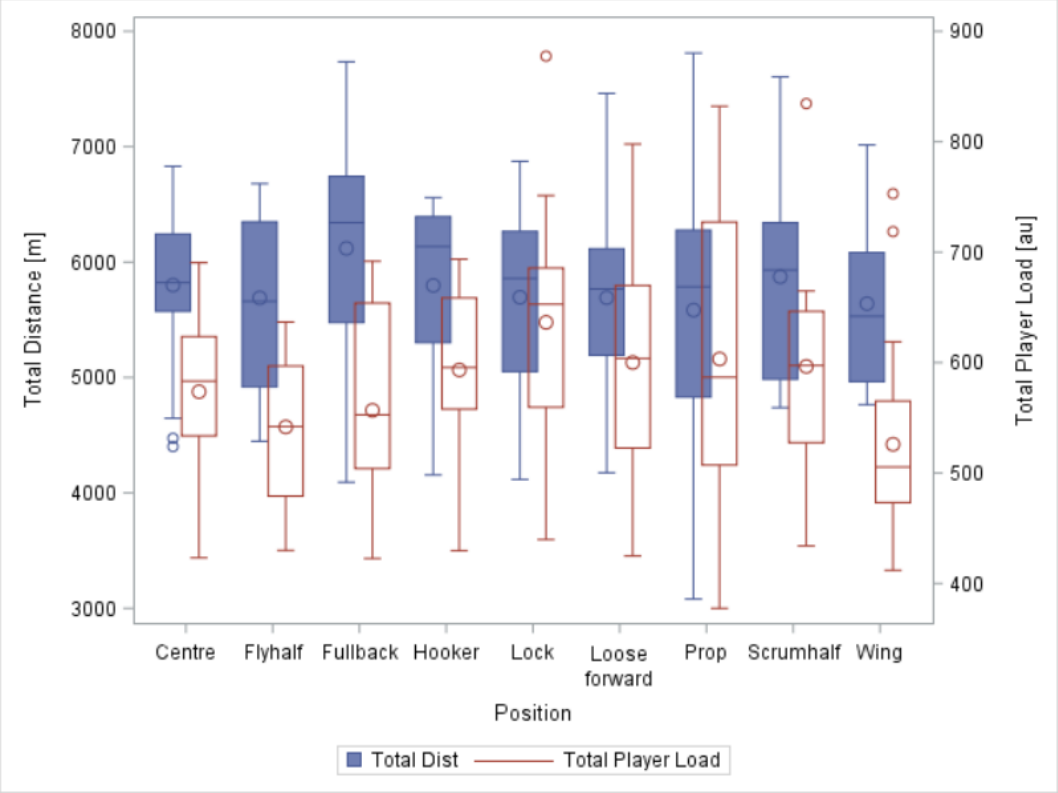

Figure 4.1. Box plot: Total Player Load [au] and Total Distance [m]

Table 4.2. Total Player Load: Statistical comparison of playing positions (pairwise P-values[a])

i/j	Centre	Flyhalf	Fullback	Hooker	Lock	Loose forward	Prop	Scrum half	Wing
Centre		0.2988	0.5133	0.8992	0.0129	0.2785	0.3313	0.7129	0.0758
Flyhalf	0.2988		0.759	0.3506	0.0024	0.0516	0.0708	0.2315	0.6542
Fullback	0.5133	0.759		0.5252	0.0089	0.1304	0.1585	0.3848	0.4369
Hooker	0.8992	0.3506	0.5252		0.0847	0.5334	0.5523	0.8535	0.1536
Lock	0.0129	0.0024	0.0089	0.0847		0.0942	0.1378	0.0999	<.0001
Loose forward	0.2785	0.0516	0.1304	0.5334	0.0942		0.9873	0.6595	0.0033
Prop	0.3313	0.0708	0.1585	0.5523	0.1378	0.9873		0.6738	0.0083
Scrumhalf	0.7129	0.2315	0.3848	0.8535	0.0999	0.6595	0.6738		0.0763
Wing	0.0758	0.6542	0.4369	0.1536	<.0001	0.0033	0.0083	0.0763	

[aPairwise] P-values from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.

Table 4.3. Total Player Load: Statistical comparison of playing positions (display of mean values and effect size)

Position	Mean[a]	Significance of pairwise comparison of playing positionb			Effect size	
					Partial ω²	$\omega = \sqrt{\omega^2}$
Lock	639.508		A		0,0946	0.31
			A			
Prop	599.155	B	A			
		B	A			
Loose forward	598.769	B	A			
		B	A			
Scrumhalf	585.424	B	A	C		
		B	A	C		
Hooker	578.095	B	A	C		
		B		C		
Centre	573.703	B		C		
		B		C		
Fullback	552.865	B		C		
		B		C		
Flyhalf	541.678	B		C		
				C		
Wing	527.651			C		

[a]Mean estimates and effect size statistic (for effect of playing position) from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.
[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.

4.3.2. Total player load per metre

Table 4.4 displays the descriptive statistics of the TPL per metre experienced by u/19 rugby players. The boxplot in Figure 4.2 provides information on the distribution of data for total player load per metre according to Figure 4.1. In the Table 4.5 the pair-wise p-values provide statistical comparisons of all player positions for the total player load (au). Further statistical comparisons can be seen in Table 4.6 which shows the mean values and effect size for all player position in terms of total player load. From these statistical comparisons it is possible to find playing positions with possible similarities or differences in TPL per metre in under-19 rugby.

The data in Table 4.4 shows that the mean TPL per metre for all positions in under-19 rugby was 0.102 TPL per metre. The highest mean TPL per metre values were experienced by the positions lock (0.112), props (0.108) and lose forwards (0.105). The lowest mean TPL values were experienced by the fullback (0.092), wings (0.093) and flyhalf (0.095) playing positions. These values agree with the TPL in Table 4.1, this shows that the TPL and TPL per metre experienced different playing position are higher in forwards than in backline players for u/19 rugby.

Table 4.4. Player Load per meter [Player Load™ (au).m^{-1}]: Descriptive statistics

	Position name									
N	**Centre**	**Flyhalf**	**Fullback**	**Hooker**	**Lock**	**Loose forward**	**Prop**	**Scrum half**	**Wing**	**All**
	22	11	10	8	19	32	19	10	20	151
Mean	0.099	0.095	0.092	0.103	0.112	0.105	0.108	0.101	0.093	0.102
Min	0.088	0.091	0.08	0.096	0.103	0.087	0.092	0.092	0.083	0.08
Median	0.099	0.095	0.086	0.101	0.11	0.107	0.107	0.102	0.094	0.102
Max	0.107	0.102	0.107	0.111	0.136	0.121	0.124	0.11	0.109	0.136

The results of the data for under-19 rugby players' TPL per metre were also illustrated using boxplots. Figure 4.2 indicates that the highest TPL per metre was experienced by the playing position locks, loose forwards and props. This correlates with the mean data values that indicate TPL and TPL per metre are highest for forwards when compared to backline players.

The backline player positions fullback and wings both experienced the lower values of TPL per metre in 11 rugby matches. Flyhalf experienced a slightly higher TPL per metre than wings. Thus, backline players experience less TPL per metre than forwards playing positions. Centres experienced the highest TPL per metre of all backline players. This data agrees with the TPL in Figure 4.1. The hooker and scrumhalf experienced similar TPL per meter.

The player position locks have the highest median followed by loose forwards, props followed by hookers and scrumhalf. This data illustrate that forward players experience the highest TPL per metre followed by scrumhalf and centre in under-19 rugby.

When comparing the inter-quartile ranges (IQR) for TPL per metre, the player position fullback and props had the largest IQR range, meaning that there was greater variation in the central 50% of the data for these positions. The TPL per metre experienced by the fullback and the props varied more from match to match. The flyhalf had the smallest IQR, followed by the centre and hooker meaning that these players experienced the least variation between matches for TPL by a playing position. Interestingly, one can then see that the TPL per metre experienced per match was by a backline player.

When comparing the upper quartile values for TPL per metre, the props showed the highest value, followed by locks, loose forwards. The hookers and scrumhalf showed a similar value. The fullback and wings positions have the smallest lower quartile values. This supports the previous finding that forwards have a higher TPL per metre than that of backline players for u/19 rugby.

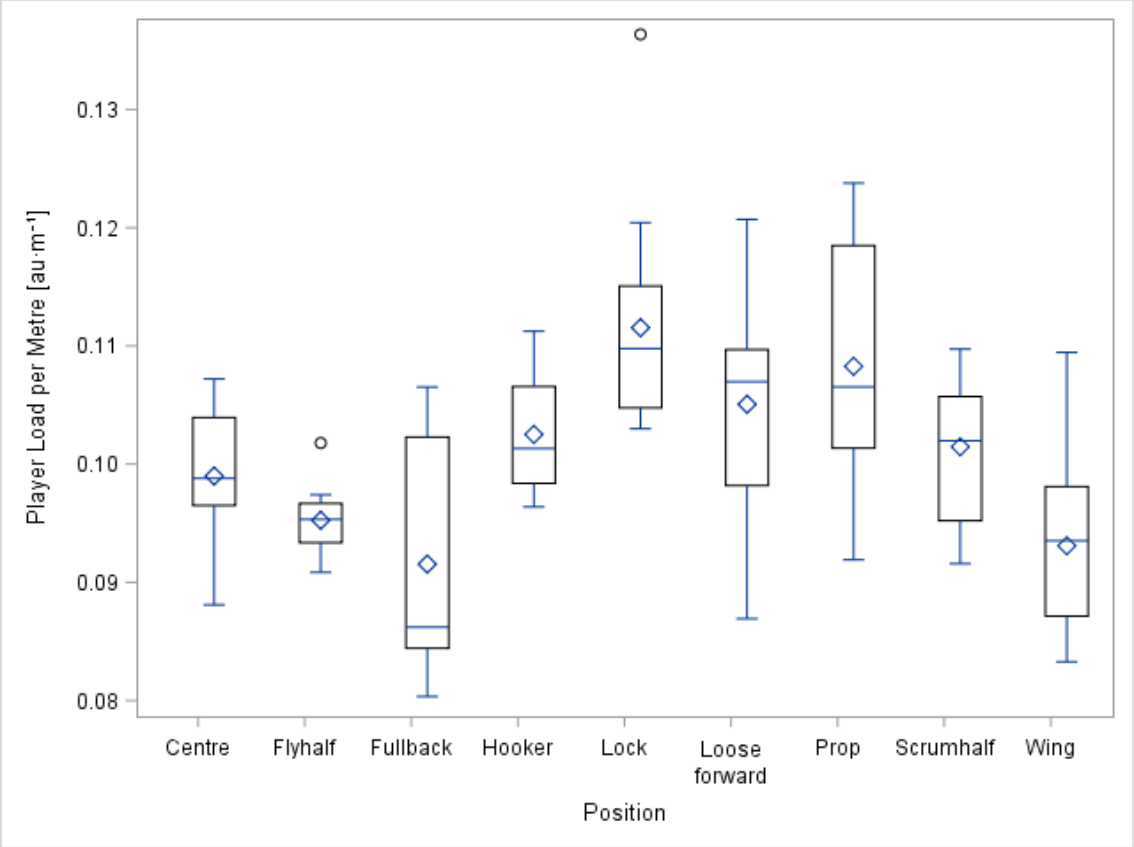

Figure 4.2. Box plot: Total Player Load per metre

Table 4.5 provides the pairwise p-values for TPL per metre. These values provide information on the statistical comparisons for the different player position in u/19 rugby. When comparing positions, the locks compared to centres, flyhalf, fullback and wings showed the greatest significant differences between player positions in TPL ($p<0.001$). The locks had the highest TPL compared to other positions. Similarities can be noted between the locks and the props. These players are both forward playing positions. The similarities between players can be noted that by the hookers and loose forwards.

Table 4.6 displays the mean values and effect size of the statistical comparisons between positions. The TPL per metre values confirm that lock had the highest TPL per metre. There is no significant difference between the hooker and scrum half. Similar TPL per metre was experienced for the loose forwards and hooker, as well as the hooker and scrumhalf. Wing and fullback had little comparison with other playing positions. The effect size ($\omega=0.64$) was relatively higher than the average in comparing different player positions.

Table 4.5. Total Player Load per metre: Statistical comparison of playing positions (pairwise P- values[a])

i/j	Centre	Flyhalf	Fullback	Hooker	Lock	Loose forward	Prop	Scrum half	Wing
Centre		0.1767	0.0098	0.2567	<.0001	0.004	0.0001	0.3901	0.0131
Flyhalf	0.1767		0.2548	0.0388	<.0001	0.0003	<.0001	0.0598	0.4632
Fullback	0.0098	0.2548		0.0024	<.0001	<.0001	<.0001	0.0036	0.5652
Hooker	0.2567	0.0388	0.0024		0.0047	0.397	0.0685	0.7624	0.0036
Lock	<.0001	<.0001	<.0001	0.0047		0.0028	0.1756	0.0007	<.0001
Loose forward	0.004	0.0003	<.0001	0.397	0.0028		0.1305	0.1865	<.0001
Prop	0.0001	<.0001	<.0001	0.0685	0.1756	0.1305		0.0196	<.0001
Scrumhalf	0.3901	0.0598	0.0036	0.7624	0.0007	0.1865	0.0196		0.0051
Wing	0.0131	0.4632	0.5652	0.0036	<.0001	<.0001	<.0001	0.0051	

[a]Pairwise P-values from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.

Table 4.6. Total Player Load per metre: Statistical comparison of playing positions (display of mean values and effect size)

Position	Mean[a]	Significance of pairwise comparison of playing positionb			Effect size	
					Partial ω^2	$\omega = \sqrt{\omega^2}$
Lock	0.1116578		A		0.4053	0.64
			A			
Prop	0.1083538	B	A			
		B				
Loose forward	0.1050525	B	C			
		B	C			
Hooker	0.1025273	B	C	D		
			C	D		
Scrumhalf	0.1014501	E	C	D		
		E		D		
Centre	0.0989896	E		D		
		E				
Flyhalf	0.0952467	E	F			
			F			
Wing	0.0931831		F			
			F			
Fullback	0.0915098		F			

[a]Mean estimates and effect size statistic (for effect of playing position) from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.
[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.

4.3.3. Distances Covered

4.3.3.1. Total Distance covered

Table 4.7 provides data for the descriptive statistics for the total distance (TD) covered during matches in the under-19 rugby season. The boxplot in Figure 4.1 provides information for the distribution of data for TD measured in metres (m). The mean value for all under-19 rugby player positions was 5733.5 m. The highest mean value for TD was by the full back position covering 6119.2 m on average. The lowest mean value for TD was by the props covering 5584.5 m on average. The centres (5800.3 m), flyhalf (5689.4 m), hooker (5796.7 m), lock (5695.8 m), loose forwards (5692.1 m) had similar TD covered during a game, compared to these positions, the scrum half (5872.6) had a slightly higher mean values for TD covered during matches.

The maximum TD covered by a player in a single match over a period of 11 matches was by the props covering 7811 m in a game for 11 rugby matches. The possible reason for this could be a replacement position during the game. The fullback covered the second most metres in a game with a TD of 7736 m. The minimum TD covered during a game was by the props covering a TD of 3080.4 m. This can indicate that there can be a great variation between matches. This can also show that the TD range that props TD varies greatly from match to match.

For all other positions the minimum TD covered during a match was between 4092.5 m by the fullback and 4764.8 m by the wing. From these values we can conclude that all positions covered a minimum TD played above the 4000 m per game, except for props. Thus, replacements used on the position prop to improve TD covered in the prop position at under-19 rugby.

The results of the data for under-19 rugby players' TD covered during a game were also illustrated using boxplots. Figure 4.1 indicates that the highest TD of a playing position was by fullback on average.

The hooker and scrumhalf covered the second highest distance on average when looking at the median line. The wings covered the least TD on average according to the median line. The following players lock, loose forwards, props all forward positions, as well as the centres a backline position all covered similar TD. Thus, these forward positions covered on average the same TD during matches.

The IQR showed that the centres had the least variation on TD during matches. Meaning that demands of TD covered by centres was from match to match similar. The props and the flyhalf had the highest IQR which means TD varied greater for these position that others in TD per match over a period of 11 matches for u/19 rugby. When comparing the upper quartile values for the TD during a match, the fullback covered the most distance this correlates with the descriptive statics in Table 4.7. The hooker and scrumhalf had similar TD after that of the fullback.

The whiskers indicate that the highest TD covered during a match as by a fullback, lock and props. But on average locks had a much lower TD covered on the top whiskers line. Thus, full backs and props made the most metres covered during a game. The whiskers showed that the smallest TD covered props, loose forwards and fullback. Props having a much lower TD than any other position.

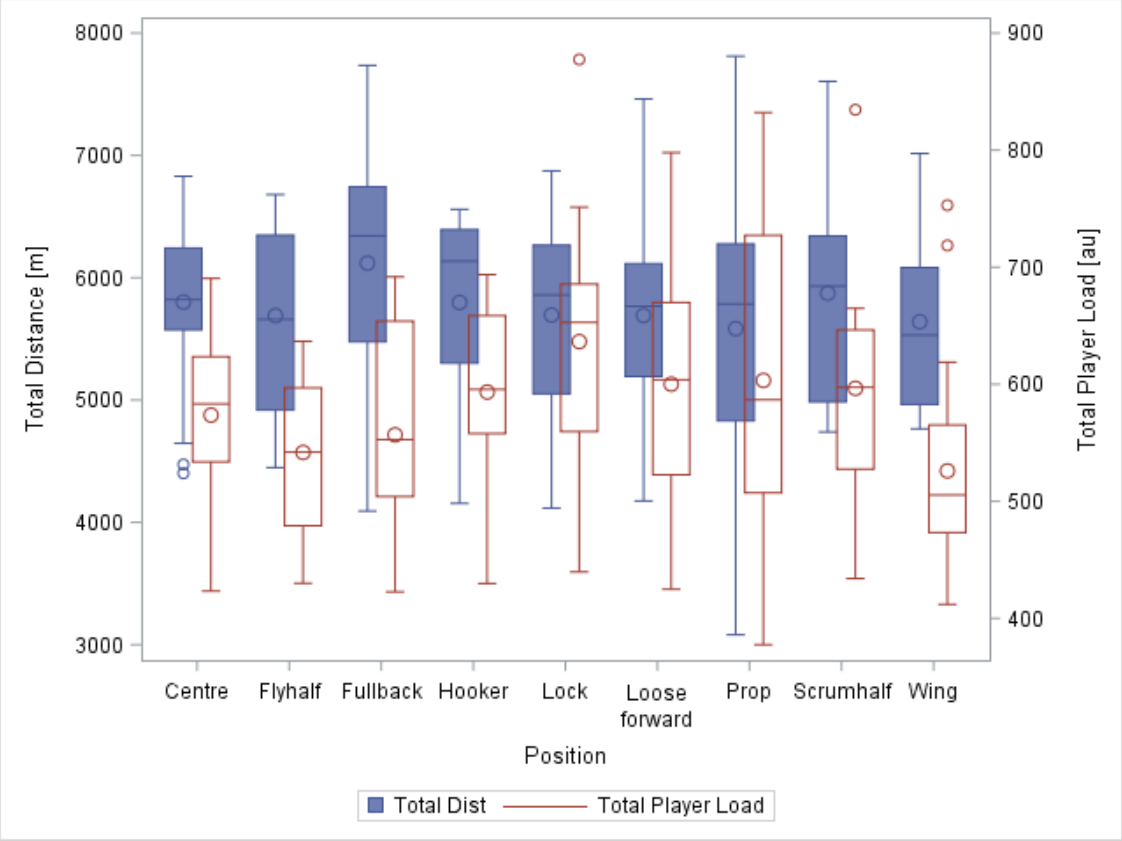

Figure 4.1. Box plot: Total Player Load [au] and Total Distance [m]

Table 4.7. Total Distance [m]: Descriptive statistics

	Position name									
N	**Centre**	**Flyhalf**	**Fullback**	**Hooker**	**Lock**	**Loose forward**	**Prop**	**Scrum half**	**Wing**	**All**
	22	11	10	8	19	32	19	10	20	151
Mean	5800.3	5689.4	6119.2	5796.7	5695.8	5692.1	5584.5	5872.6	5640.4	5733.5
Min	4401.3	4447.6	4092.5	4155.1	4117	4175.2	3080.4	4739	4764.8	3080.4
Median	5821.9	5659.9	6341.7	6134.6	5858.9	5767	5785.4	5931.1	5530.9	5813.2
Max	6829.9	6679.7	7736	6559.2	6873.4	7461.3	7811	7605.8	7015.2	7811

Table 4.8 provides the pairwise p-values for TD covered in match-play. These values provide information on the statistical comparisons for the different player position in u/19 rugby. When comparing positions, there were little significant difference for all positions. Therefore, all positions had similar distances covered. Although, when comparing the fullback and the props, there was a higher significant difference for TD covered during a match.

The scrumhalf, centre, flyhalf and wings (all backline players), as well as the hooker, lock and loose forwards (all forwards) had comparable values. This suggests that the TD covered by these positions were all relatively similar.

Table 4.9 displays the mean values and effect size of the statistical comparisons between positions. The TD values confirm that fullback covered the most distance in a game, followed by the centre and the scrumhalf, all backline players. The lock covered the most TD of all forward positions, followed by the loose forwards, hooker. These forward positions were all relatively similar in TD. The props covered the least TD during a match. The effect size (ω=0) was small in comparing different player positions.

Table 4.8. Total Distance: Statistical comparison of playing positions (pairwise P-values[a])

i/j	Centre	Flyhalf	Fullback	Hooker	Lock	Loose forward	Prop	Scrum half	Wing
Centre		0.6615	0.275	0.5946	0.7005	0.5342	0.2233	0.8896	0.4792
Flyhalf	0.6615		0.1866	0.8981	0.9141	0.9757	0.5594	0.8041	0.8784
Fullback	0.275	0.1866		0.1807	0.1712	0.1052	0.0427	0.2948	0.1029
Hooker	0.5946	0.8981	0.1807		0.8126	0.9016	0.7036	0.7236	0.9955
Lock	0.7005	0.9141	0.1712	0.8126		0.8592	0.4198	0.8631	0.7589
Loose forward	0.5342	0.9757	0.1052	0.9016	0.8592		0.4684	0.7428	0.8699
Prop	0.2233	0.5594	0.0427	0.7036	0.4198	0.4684		0.3994	0.6088
Scrumhalf	0.8896	0.8041	0.2948	0.7236	0.8631	0.7428	0.3994		0.6694
Wing	0.4792	0.8784	0.1029	0.9955	0.7589	0.8699	0.6088	0.6694	

[a]Pairwise P-values from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.

Table 4.9. Total Distance: Statistical comparison of playing positions (display of mean values and effect size)

Position	Mean[a]	Significance of pairwise comparison of playing positionb		Effect size	
				Partial ω²	$\omega = \sqrt{\omega^2}$
Fullback	6087.2		A	0	0
			A		
Centre	5800.3	B	A		
		B	A		
Scrumhalf	5763.9	B	A		
		B	A		
Lock	5717.5	B	A		
		B	A		
Flyhalf	5689.4	B	A		
		B	A		
Loose forward	5682.1	B	A		
		B	A		
Wing	5650	B	A		
		B	A		
Hooker	5648.3	B	A		
		B			
Prop	5537.4	B			

[a]Mean estimates and effect size statistic (for effect of playing position) from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.
[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.

4.3.3.2. Total distances covered in velocity bands

The data in Table 4.10 provides information on the TD velocity bands (VB) 1 to 5. This shows the mean values of all velocities during a match in metres (m).:

Table 4.10. Velocity Bands: Distance [m]: Descriptive statistics

Variable		Position name									
		Centre	Flyhalf	Fullback	Hooker	Lock	Loose forward	Prop	Scrum half	Wing	All
	N	21	11	10	8	19	32	18	10	20	149
Velocity Band 1 Distance [m]	Mean	2618	2567.2	3318.7	2515.1	2760.4	2767.2	2893.5	2303.7	3012.1	2771
	Min	1945.1	2149	2324.1	1737.9	1676.4	2132.1	1545.9	1735	2165.7	1545.9
	Median	2602.2	2526.9	3227	2577.4	2765.8	2712.2	2928.2	2265.8	2945.7	2687.1
	Max	3553.1	3574.9	4048.2	3188	3662.5	3856.3	3873.7	3520.9	4647.5	4647.5
Velocity Band 2 Distance [m]	Mean	2107.5	2203.9	1958.7	2757	2353.9	2203.5	2208.9	2617	1697	2182.9
	Min	1395.2	1451.9	1269.5	1914.7	1745.2	1367.2	1148.9	1840	1020.8	1020.8
	Median	2131.6	2165.3	1898.7	2884	2219.5	2175.4	2327.6	2691.5	1702.4	2160.8
	Max	2650.6	2753.7	2687.3	3285.6	3228.5	2945.8	2976.6	3322.9	2369.7	3322.9
Velocity Band 3 Distance [m]	Mean	506.8	611.1	417.2	348.9	368	443.2	256.3	645.5	375.5	430.1
	Min	259.8	375.7	289.8	236.9	190.5	256.4	86.2	331.5	272.3	86.2
	Median	465.8	569.9	361.7	328.8	383.9	419	235.7	627.3	347.4	393.8
	Max	907.2	1045.1	665.9	535	623.9	767.2	590.8	1023.5	629	1045.1
Velocity Band 4 Distance [m]	Mean	358.5	204.9	249.7	126.5	162.2	210	82.2	230	277.7	217.6
	Min	198.5	136.5	149.3	55.6	36	92.2	8.4	123.4	128.2	8.4
	Median	345.5	213.5	244.5	117.5	153.9	186.3	70.9	230.9	270	205.3
	Max	560.3	298.5	425.5	199.3	283.7	426.4	272.5	405.1	501.9	560.3
Velocity Band 5 Distance [m]	Mean	358.5	204.9	249.7	126.5	162.2	210	82.2	230	277.7	217.6
	Min	198.5	136.5	149.3	55.6	36	92.2	8.4	123.4	128.2	8.4
	Median	345.5	213.5	244.5	117.5	153.9	186.3	70.9	230.9	270	205.3
	Max	560.3	298.5	425.5	199.3	283.7	426.4	272.5	405.1	501.9	560.3

4.3.3.2.1. Total distance [m] in Velocity Band 1

The TD mean value for all the players in VB1 was 2771 m. The highest mean values were achieved by the full back 3318.7m and the wings 3012.1 m. The lowest mean value was by the scrumhalf covering 2303.7 m. Similarities can be seen by all forward positions, lock, loose forwards and props.

The maximum distance in VB 1 covered by a player in a single match was by the wings 4648 m and the fullback 4048.2 m. The minimum distance covered by a player in VB 1 was the props 1545.9 m and locks 1674.4 m. This can indicate that there can be a great variation between matches for different playing positions.

The results of the data for under-19 rugby players' VB1 covered during a game were also illustrated using boxplots. Figure 4.3 indicates that the highest distance covered in VB1 was by the fullback and the distance least covered was by the scrumhalf. The fullback had the largest IQR also had the highest median value. The scrumhalf showed the lowest median and smallest lower quartile value as well as the smallest upper quartile value. This corresponds with the findings that scrumhalf had the lowest distance covered in VB1. The fullback also revealed the highest upper quartile value and largest lower quartile values. Indicating that the fullback covered the most distance by a player in VB1. Notably the fullback also had the highest IQR, meaning that the distance covered greatly differed from match to match.

Table 4.11 provides the pairwise p-values for distance covered in in VB1. These values provide information on the statistical comparisons for the different player position in u/19 rugby. When comparing positions, fullback showed no significant differences between for that of hooker, centre and scrumhalf These positions covered similar distances. All other players had similar distances covered in VB1.

Table 4.12 displays the mean values and effect size of the statistical comparisons between positions. The distances for VB1 confirm that fullback covered the most distance in a game. The scrumhalf the lowest distance. Props had the highest distance amongst forward positions, although props, loose forwards and locks all covered similar distances in VB1. The effect size (ω=0.44) was relatively average in comparing different player positions.

Table 4.11. Velocity Band 1 Distance: Statistical comparison of playing positions (pairwise P- values[a])

i/j	Centre	Flyhalf	Fullback	Hooker	Lock	Loose forward	Prop	Scrum half	Wing
Centre		0.7564	<.0001	0.4281	0.3458	0.2254	0.0718	0.0435	0.0055
Flyhalf	0.7564		0.0001	0.644	0.2744	0.1926	0.0696	0.1283	0.0088
Fullback	<.0001	0.0001		<.0001	0.0012	0.0007	0.0113	<.0001	0.0661
Hooker	0.4281	0.644	<.0001		0.139	0.0927	0.0342	0.343	0.0047
Lock	0.3458	0.2744	0.0012	0.139		0.8871	0.389	0.0065	0.0712
Loose forward	0.2254	0.1926	0.0007	0.0927	0.8871		0.4117	0.0023	0.0602
Prop	0.0718	0.0696	0.0113	0.0342	0.389	0.4117		0.0007	0.3612
Scrumhalf	0.0435	0.1283	<.0001	0.343	0.0065	0.0023	0.0007		<.0001
Wing	0.0055	0.0088	0.0661	0.0047	0.0712	0.0602	0.3612	<.0001	

[a]Pairwise P-values from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.

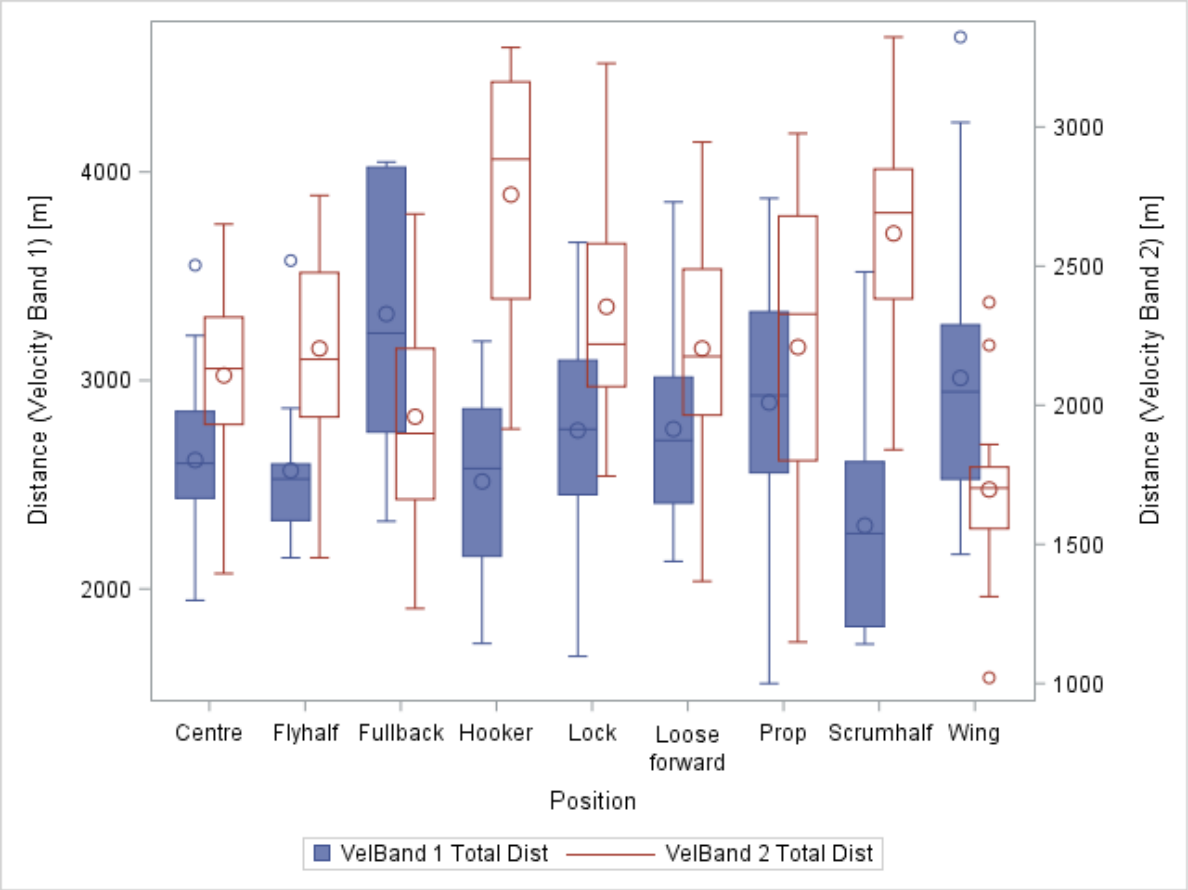

Figure 4.3. Box plot: Distance covered in Velocity band 1 and Velocity band 2

Table 4.12. Velocity Band 1 Total Distance [m]: Statistical comparison of playing positions (display of mean values and effect size)

Position	Mean[a]	Significance of pairwise comparison of playing positionb			Effect size	
					Partial ω²	$\omega = \sqrt{\omega^2}$
Fullback	3318.3		A		0.1933	0.44
			A			
Wing	3003.6	B	A			
		B				
Prop	2873.5	B	C			
		B	C			
Loose forward	2767.1	B	C	D		
		B	C	D		
Lock	2749	B	C	D		
			C	D		
Centre	2617.8		C	D		
			C	D		
Flyhalf	2567.2	E	C	D		
		E		D		
Hooker	2472.7	E		D		
		E				
Scrumhalf	2274.8		E			

[a]Mean estimates and effect size statistic (for effect of playing position) from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.
[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.

4.3.3.2.2. Total distance [m] in Velocity Band 2

The TD mean value for all the players in VB2 was 2182.9 m. The highest mean values were achieved by the hooker 2757 m and the scrumhalf 2617 m. The lowest mean value was by the wings covering 1697 m and the fullback 1958.7 m. Similarities can be found between forward positions, lock, loose forwards and props as well as backline positions flyhalf and centres.

The maximum distance in VB2 covered by a player in a single match was by the scrumhalf 3322.9 m. The minimum distance covered by a player in VB2 was by the wings 1020.8 m. This can indicate that there can be a great variation between matches for different playing positions in VB2.

The results of the data for under-19 rugby players' VB2 covered during a game were also illustrated using boxplots. Figure 4.3 indicates that the highest distance covered in VB2 was

by the hooker, the distance least covered was by the wing and scrumhalf. The hooker and props had the largest IQR. Meaning that matches varied from one another for hooker and props. The smallest IQR was by wings, showing that from match to match there is little difference in distance covered in VB2.

The hooker had the highest median value. The scrumhalf and wings showed the lowest median values. The highest upper quartile was by the hooker, the lowest lower quartile by the scrumhalf. Therefore, hookers covered the highest distance during VB2. The wings and scrumhalf covered the lowest distances in VB2.

Table 4.13 provides the pairwise p-values for distance covered in in VB2. These values provide information on the statistical comparisons for the different player position in u/19 rugby. When comparing positions, the hooker was significantly difference compared to the fullback and the wings p<0.0001. The forward positions of hooker, lock and loose forwards and props all had similar distances covered together with the backline position of scrumhalf in VB2.

Table 4.14 displays the mean values and effect size of the statistical comparisons between positions. The distances for VB2 confirm that the hookers covered the most distance in a match. The wings covered the lowest distance. The forwards all had similar values above 2189.4 m for prop to 2369.4 m for the locks in VB2. The effect size (ω=0.56) was relatively average in comparing different player positions.

Table 4.13. Velocity Band 2 Distance: Statistical comparison of playing positions (pairwise P- values[a])

i/j	Centre	Flyhalf	Fullback	Hooker	Lock	Loose forward	Prop	Scrum half	Wing
Centre		0.4187	0.2402	0.0001	0.0166	0.3169	0.4196	0.0008	0.0006
Flyhalf	0.4187		0.0867	0.0048	0.2183	0.9546	0.9153	0.0213	0.0003
Fullback	0.2402	0.0867		<.0001	0.0022	0.0446	0.0738	0.0001	0.0946
Hooker	0.0001	0.0048	<.0001		0.0419	0.0008	0.0016	0.4996	<.0001
Lock	0.0166	0.2183	0.0022	0.0419		0.0947	0.1243	0.1627	<.0001
Loose forward	0.3169	0.9546	0.0446	0.0008	0.0947		0.9438	0.0049	<.0001
Prop	0.4196	0.9153	0.0738	0.0016	0.1243	0.9438		0.0082	<.0001
Scrumhalf	0.0008	0.0213	0.0001	0.4996	0.1627	0.0049	0.0082		<.0001
Wing	0.0006	0.0003	0.0946	<.0001	<.0001	<.0001	<.0001	<.0001	

[a]Pairwise P-values from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.

Table 4.14. Velocity Band 2 Total Distance [m]: Statistical comparison of playing positions (display of mean values and effect size)

Position	Mean[a]	Significance of pairwise comparison of playing positionb		Effect size	
				Partial ω²	$\omega = \sqrt{\omega^2}$
Hooker	2677.6		A	0.3083	0.56
			A		
Scrumhalf	2563.8	B	A		
		B			
Lock	2369.4	B	C		
			C		
Flyhalf	2203.9	D	C		
		D	C		
Loose forward	2196.8	D	C		
		D	C		
Prop	2189.4	D	C		
		D			
Centre	2097.3	D			
		D			
Fullback	1937.3	D	E		
			E		
Wing	1706.3		E		

[a]Mean estimates and effect size statistic (for effect of playing position) from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.
[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.

4.3.3.2.3. Total distance [m] in Velocity Band 3

The TD mean value for all the players in VB3 was 430.1 m. The highest mean values were achieved by the scrumhalf 645.5 m and the flyhalf 611.1 m. The lowest mean value was by the props covering 256.3 m and the hooker 348.9 m. Similarities can be found between forward positions, hooker and lock as well as backline position wings. Centres covered 506.8 m, flyhalf and the scrumhalf covered the most distance in VB3, all players belonging to the backline.

The maximum distance in VB3 covered by a player in a single match was by the flyhalf 1045.1 m, and the scrumhalf 1023.5 m, centres 907.2 m also covered a relatively high distance for VB3. The minimum distance covered by a player in VB3 was by the props 86.2 m and locks 190.5 m. This can indicate that there can be a great variation between matches for different playing positions in VB3.

The results of the data for under-19 rugby players' VB3 covered during a game were also illustrated using boxplots. Figure 4.4 indicates that the highest distance covered in VB3 was by the flyhalf and scrumhalf. The prop, hooker and wings covered the least distance in VB3. The flyhalf had the largest IQR. Meaning that matches varied from one another for hooker and props in VB3. The smallest IQR was by the prop hooker and wings, showing that from match to match there is little difference in distance covered in VB3.

The scrumhalf and flyhalf had the highest median values. The prop, hooker and wings showed the lowest median values. The highest upper quartile was by the flyhalf and scrumhalf, the lowest lower quartile by the props. Therefore, scrumhalf and flyhalf covered the highest distance during VB3. The prop, hooker and wings covered the lowest distances in VB3.

Table 4.13 provides the pairwise p-values for distance covered in in VB2. These values provide information on the statistical comparisons for the different player position in u/19 rugby. When comparing positions, the hooker had significant difference compared to the fullback and the wings $p<0.0001$. The forwards hooker, lock and loose forwards and props all had similar distances covered, similarly to the backline position of scrumhalf in VB2.

Table 4.15 displays the mean values and effect size of the statistical comparisons between positions. The distances for VB3 confirm that the scrumhalf, flyhalf and centres had comparable distances, with scrumhalf achieving the highest distance of 631.43 m. Loose forwards covered the highest distance of 442.4m amongst the forwards. Lock and hookers covered similar distances, while the props had the lowest metreage of 247.7 m in VB3. The effect size ($\omega=0.66$) was above average when comparing different player positions.

Table 4.15. Velocity Band 3 Distance: Statistical comparison of playing positions (pairwise P- values[a])

i/j	Centre	Flyhalf	Fullback	Hooker	Lock	Loose forward	Prop	Scrum half	Wing
Centre		0.0166	0.0446	0.0008	0.0007	0.0566	<.0001	0.006	0.0008
Flyhalf	0.0166		0.0002	<.0001	<.0001	<.0001	<.0001	0.6916	<.0001
Fullback	0.0446	0.0002		0.1708	0.412	0.5101	0.0005	<.0001	0.4469
Hooker	0.0008	<.0001	0.1708		0.4351	0.0262	0.0758	<.0001	0.3969
Lock	0.0007	<.0001	0.412	0.4351		0.0551	0.0011	<.0001	0.9344
Loose forward	0.0566	<.0001	0.5101	0.0262	0.0551		<.0001	<.0001	0.0629
Prop	<.0001	<.0001	0.0005	0.0758	0.0011	<.0001		<.0001	0.0007
Scrumhalf	0.006	0.6916	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001
Wing	0.0008	<.0001	0.4469	0.3969	0.9344	0.0629	0.0007	<.0001	

[a]Pairwise P-values from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.

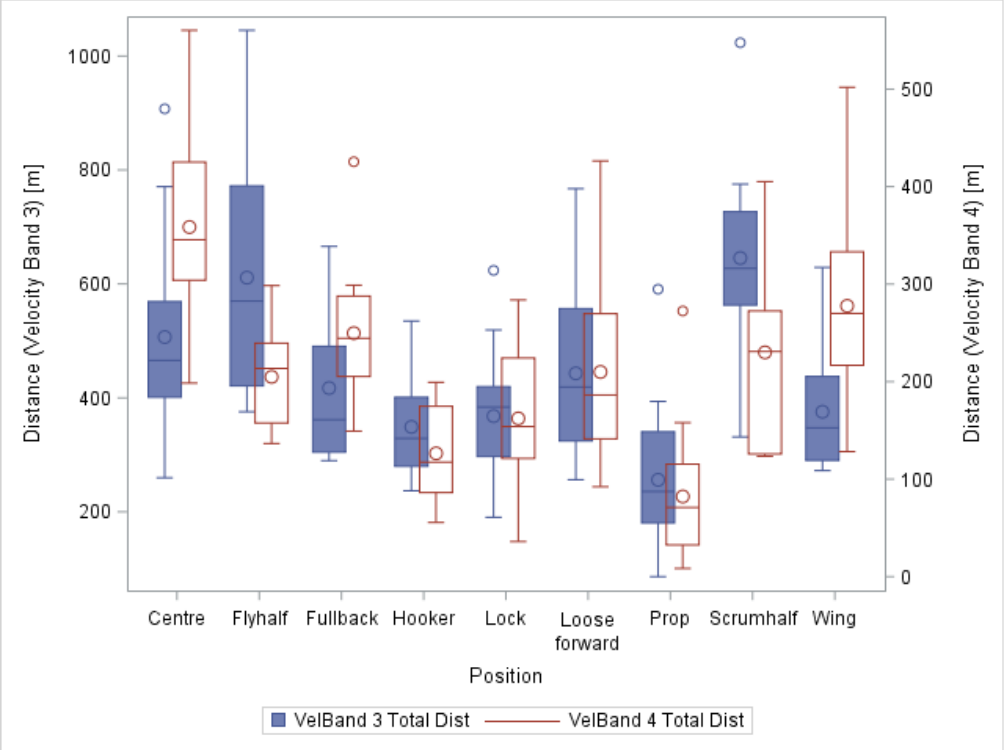

Figure 4.4. Box plot: Distance covered in Velocity band 3 and Velocity band 4

Table 4.16. Velocity Band 3 Total Distance [m]: Statistical comparison of playing positions (display of mean values and effect size)

Position	Mean[a]	Significance of pairwise comparison of playing positionb			Effect size	
					Partial ω²	$\omega = \sqrt{\omega^2}$
Scrumhalf	631.43			A	0.4315	0.66
				A		
Flyhalf	611.088			A		
Centre	505.418			B		
				B		
Loose forward	442.265		C	B		
			C			
Fullback	414.257		C	D		
			C	D		
Wing	379.57		C	D		
			C	D		
Lock	376.48		C	D		
				D		
Hooker	337.56		E	D		
			E			
Prop	247.787		E			

[a]Mean estimates and effect size statistic (for effect of playing position) from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.
[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.

4.3.3.2.4. Total distance [m] in Velocity Band 4

The TD mean value for all the players in VB 4 and 5 was 217.6 m. The highest mean values were achieved by the centres 358.5 m and the wings 277.7 m. The lowest mean value was by the props 82.2 m, the locks and the loose forwards also had lower distances. Similarities can be found between forward positions having lower distances for props, hooker and lock when compared to backline positions centres, wings, fullback and flyhalf.

The maximum distance in VB 4&5 covered by a player in a single match was by the centre 560.3 m, the wings 501.9 m and the fullback 425.5 m. The minimum distance covered by a player in VB 4&5 was by the props 8.4 m and locks 36 m. This can indicate that there can be a great variation between matches for different playing positions in VB4 and that backline players had a much higher distance covered compared to forwards.

The results of the data for under-19 rugby players' distance covered in VB4 during a match were also illustrated using boxplots. Figure 4.4 indicates that centres covered the highest distance in VB4. The prop covered the least distance in VB4. The scrumhalf had the largest IQR. Meaning that matches varied from one another for scrumhalf in VB4. The IQR was relatively small for the positions flyhalf, fullback, hooker and props, this showing that from match to match there was little difference in distance covered in VB4.

The centres had the highest median values. The prop showed the lowest median values. Similarities between lock, hooker, loose forward showed lower median values. The upper quartile was highest in the centres position, while lowest position was by the prop, hooker and locks, all forwards. In the lower quartile, centres had the highest values and props the lowest, followed by hookers and locks all forwards. Thus, forwards covered a significantly lower metreage than backline players with centres achieving the highest metreage for all players in VB4.

Table 4.17 provides the pairwise p-values for distance covered in in VB4. These values provide information on the statistical comparisons for the different player position in u/19 rugby. When comparing positions, the centres showed significant difference compared to other positions. The loose forwards compared the highest distance amongst forwards. Lock, hooker and prop had lower distances, while props covered the least distances of all players in VB4.

Table 4.18 displays the mean values and effect size of the statistical comparisons between positions. The distances for VB4 confirm that the backline players centres, wings and scrumhalf all had higher distances than forwards. Centres covered the most metreage of 356.9 m. Loose forwards covered 208.9 m and had the highest metreage of all forwards in VB4. The effect size (ω=0.75) was above average when comparing different player positions.

Table 4.17. Velocity Band 4 Distance: Statistical comparison of playing positions (pairwise P- values[a])

i/j	Centre	Flyhalf	Fullback	Hooker	Lock	Loose forward	Prop	Scrum half	Wing
Centre		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0006
Flyhalf	<.0001		0.1762	0.0126	0.1782	0.867	<.0001	0.5656	0.0046
Fullback	<.0001	0.1762		0.0003	0.0055	0.1414	<.0001	0.4461	0.2126
Hooker	<.0001	0.0126	0.0003		0.1181	0.0022	0.1578	0.0031	<.0001
Lock	<.0001	0.1782	0.0055	0.1181		0.0511	0.0002	0.0532	<.0001
Loose forward	<.0001	0.867	0.1414	0.0022	0.0511		<.0001	0.5953	0.0005
Prop	<.0001	<.0001	<.0001	0.1578	0.0002	<.0001		<.0001	<.0001
Scrumhalf	<.0001	0.5656	0.4461	0.0031	0.0532	0.5953	<.0001		0.0346
Wing	0.0006	0.0046	0.2126	<.0001	<.0001	0.0005	<.0001	0.0346	

[a]Pairwise P-values from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.

Table 4.18. Velocity Band 4 Total Distance [m]: Statistical comparison of playing positions (display of mean values and effect size)

Position	Mean[a]	Significance of pairwise comparison of playing positionb		Effect size	
				Partial ω²	$\omega = \sqrt{\omega^2}$
Centre	356.9063		A	0.5571	0.75
Wing	280.4409		B		
			B		
Fullback	246.4222	C	B		
		C			
Scrumhalf	222.4603	C	D		
		C	D		
Loose forward	208.9498	C	D		
		C	D		
Flyhalf	204.8555	C	D		
			D		
Lock	168.9969	E	D		
		E			
Hooker	122.2899	E	F		
			F		
Prop	79.7236		F		

[a]Mean estimates and effect size statistic (for effect of playing position) from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.
[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.

4.3.3.2.5. Total distance [m] in Velocity Band 5

The results of the data for under-19 rugby players' distance covered in VB5 during a match were also illustrated using boxplots. Figure 4.5 indicates that wings covered the highest distance followed by centres and fullback in VB5.

The prop covered the lowest distance in VB5. All forwards had lower values compared to backline players, except for scrumhalf. Scrumhalf and loose forwards covered similar distances. The wings had the largest IQR. Meaning that matches varied from one another for scrumhalf in VB5. The IQR was relatively small for the positions props. All other positions had a relatively small IQR. This shows that from match to match there was little difference in distance covered in VB5.

The wing had the highest median values. The prop showed the lowest median values. Similarities between lock, hooker, loose forward showed lower median values compared to all positions. The upper quartile was highest in the wings position, while lowest position was by the prop, hooker and locks, all forwards. In the lower quartile, wings had the highest values and props the lowest, followed by hookers and locks all forwards. Thus, forwards covered a significantly lower metreage than backline players with wings achieving the highest metreage for all players in VB5.

Table 4.19 provides the pairwise p-values for distance covered in in VB5. These values provide information on the statistical comparisons for the different player position in u/19 rugby. When comparing positions, the centres showed significant difference compared to other positions. The loose forwards compared the highest distance amongst forwards. Lock, hooker and prop had lower distances, while props covered the least distances of all players in VB5.

Table 4.20 displays the mean values and effect size of the statistical comparisons between positions. The distances for VB5 confirm that the backline players wings metreage of 280.7 m had the highest distances compared to all other positions. Centres covered the second most distance of 232.9 m. Loose forwards covered 67.9 m and had the highest metreage of all forwards in VB5. The props only covered 19 m in VB5. The effect size (ω=0.78) was high when comparing different player positions.

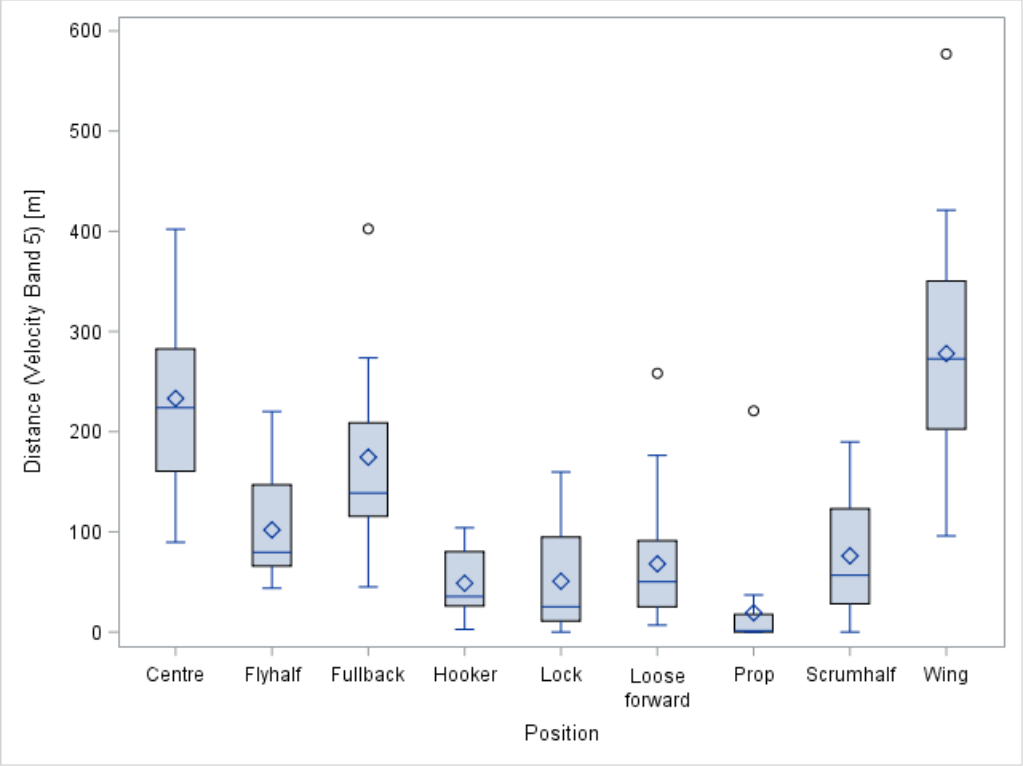

Figure 4.5. Box plot: Distance covered in Velocity band 5

Table 4.19. Velocity Band 5 Distance: Statistical comparison of playing positions (pairwise P- values[a])

i/j	Centre	Flyhalf	Fullback	Hooker	Lock	Loose forward	Prop	Scrum half	Wing
Centre		<.0001	0.0331	<.0001	<.0001	<.0001	<.0001	<.0001	0.0331
Flyhalf	<.0001		0.0211	0.0911	0.0816	0.1722	0.003	0.3305	<.0001
Fullback	0.0331	0.0211		0.0002	<.0001	<.0001	<.0001	0.0016	0.0002
Hooker	<.0001	0.0911	0.0002		0.7601	0.4287	0.3959	0.4408	<.0001
Lock	<.0001	0.0816	<.0001	0.7601		0.5234	0.1354	0.5449	<.0001
Loose forward	<.0001	0.1722	<.0001	0.4287	0.5234		0.0229	0.8859	<.0001
Prop	<.0001	0.003	<.0001	0.3959	0.1354	0.0229		0.0657	<.0001
Scrumhalf	<.0001	0.3305	0.0016	0.4408	0.5449	0.8859	0.0657		<.0001
Wing	0.0331	<.0001	0.0002	<.0001	<.0001	<.0001	<.0001	<.0001	

[a]Pairwise P-values from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.

Table 4.20. Velocity Band 5 Total Distance [m]: Statistical comparison of playing positions (display of mean values and effect size)

Variable	Position	Mean[a]	Significance of pairwise comparison of playing positionb		Effect size	
					Partial ω²	$\omega = \sqrt{\omega^2}$
Total distance [m]	Wing	280.7499		A	0.6141	0.78
	Centre	232.9628		B		
	Fullback	174.3139		C		
	Flyhalf	101.9536		D		
				D		
	Scrumhalf	71.6735	E	D		
			E	D		
	Loose forward	67.9728	E	D		
			E	D		
	Lock	54.7991	E	D		
			E	D		
	Hooker	45.5849	E	D		
			E			
	Prop	19.6993	E			

[a]Mean estimates and effect size statistic (for effect of playing position) from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.
[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.

4.3.3.3. Total distance percentages covered in velocity bands

The Table 4.21 provides data for the descriptive statistics of the total distance percentages (td%) spent in velocity bands (VB) 1 to 5 for all the different playing positions in u/19 rugby. The number (N) of players tested by GPS technology was 151. The boxplot in Figure 4.6 provides information on VB1 and 2 for td%. Figure 4.7 provides information on VB3 to 5 for the distribution of data for td%.

The average mean values for td% in each velocity band (VB) was classified in VB 1 - 5.

Table 4.21. Velocity Bands: Distance Percentages: Descriptive statistics

Variable		Position name									All
		Centre	Flyhalf	Fullback	Hooker	Lock	Loose forward	Prop	Scrum half	Wing	
	N	22	11	10	8	19	32	19	10	20	151
Velocity Band 1 Distance %	Mean	44.9	45.3	54.4	43.4	48.4	48.9	53.1	38.9	53.2	48.5
	Min	36.6	37.4	42.4	34.1	39	34.6	40.2	34.8	42.6	34.1
	Median	45	44.3	54.8	42.1	48.5	49.6	52.1	37.2	50.7	48.4
	Max	53.6	56	64.5	52.7	58.5	60.4	67.3	46.3	66.6	67.3
Velocity Band 2 Distance %	Mean	36	38.6	31.9	47.5	41.5	38.5	40.5	44.8	30.2	38.1
	Min	29.7	32.6	26.5	39.6	32.4	30.5	26.1	38.8	20.6	20.6
	Median	36	38.6	31.8	48.6	40.7	39.4	41.7	44.7	31.2	38.6
	Max	41.8	43.8	39.4	52.8	51.4	45.6	50.1	54.6	35.1	54.6
Velocity Band 3 Distance %	Mean	8.8	10.7	6.8	6.1	6.4	7.7	4.6	11.1	6.7	7.5
	Min	5.7	5.9	4.6	4.5	4	5.1	1.8	6.6	4.3	1.8
	Median	8	10.2	6.5	5.3	6.6	7.3	4.5	11.3	6.2	6.8
	Max	13.6	16.5	9.4	8.8	9.1	11.6	9.1	16.4	10.3	16.5
Velocity Band 4 Distance %	Mean	6.2	3.6	4.1	2.2	2.8	3.7	1.4	3.9	4.9	3.8
	Min	4	2.2	2.5	1.1	0.6	1.6	0.3	1.6	2.3	0.3
	Median	6.2	3.8	4	2.5	2.7	3.5	1.6	4.5	4.9	3.8
	Max	10.2	4.7	6.6	3	4.6	7	4.2	5.8	7.4	10.2
Velocity Band 5 Distance %	Mean	4.1	1.8	2.8	0.8	0.9	1.2	0.4	1.3	5	2.1
	Min	1.5	0.8	1.1	0	0	0.1	0	0	2	0
	Median	4	1.5	2.4	0.8	0.5	0.9	0	1.1	4.8	1.5
	Max	6.9	3.5	6.5	1.7	2.3	4.8	3.4	3	10.7	10.7

4.3.3.3.1. Total distance percentages covered in velocity band 1

The td% mean value for all the players in VB1 was 48.5%. The highest mean values were achieved by the fullback with 54.4% and the props 53.1%. The lowest mean value was by the scrumhalf 38.9%. Similarities can be seen by fullbacks as highest percentage in VB1, with props and wings having high td% in VB1. The forward positions lock and loose forwards ranged between 48-53%. The centre, flyhalf and hooker had similar td%. All players had high td% in VB1.

The maximum td% in VB 1 in a single match was by the fullback, props and wings. Showing that these positions spent the most time in VB1 of all players. The minimum td% by a player in VB 1 was the scrumhalf at 34.8% as well as hookers and loose forwards. This shows that the scrumhalf walked the least during matches compared to other positions. This can indicate

that there can be a great variation between matches for different playing positions, although all positions had high td% in VB1.

The results of the data for under-19 rugby players' VB1 covered during a game were also illustrated using boxplots. Figure 4.6 indicates that the highest td% according to the median in VB1 was by the fullback and the td% with least time spent was by the scrumhalf. The wing and fullback had the largest IQR meaning that the td% greatly differed from match to match. The scrumhalf showed the lowest median and smallest lower quartile value as well as the smallest upper quartile value. This corresponds with the findings that scrumhalf had the lowest td% in VB1. Therefore, the fullback walked the most and the scrumhalf walked the least during match play when comparing td%. The fullback position had the highest upper quartile value and largest lower quartile values. Indicating that the fullback spent the most time by a player in VB1.

Table 4.22 provides the pairwise p-values for td% in VB1. These values provide information on the statistical comparisons for the different player position in u/19 rugby. When comparing positions, the fullback, centre and wings both showed significant differences compared to that of other positions $p<0.0001$. The prop, loose forwards, fullback and wing all had similar td%. When comparing all positions, all players had a relatively high td% in VB1. Meaning that all players spent he most time standing or walking in a rugby match.

Table 4.23 displays the mean values and effect size of the statistical comparisons between positions. The VB1 confirm that fullback had the highest td% of all positions. The scrumhalf the lowest td%. Props had the highest td% amongst forward positions, although props, loose forwards and locks all had similar td% in VB1. The effect size ($\omega=0.63$) was significantly high in comparing different player positions.

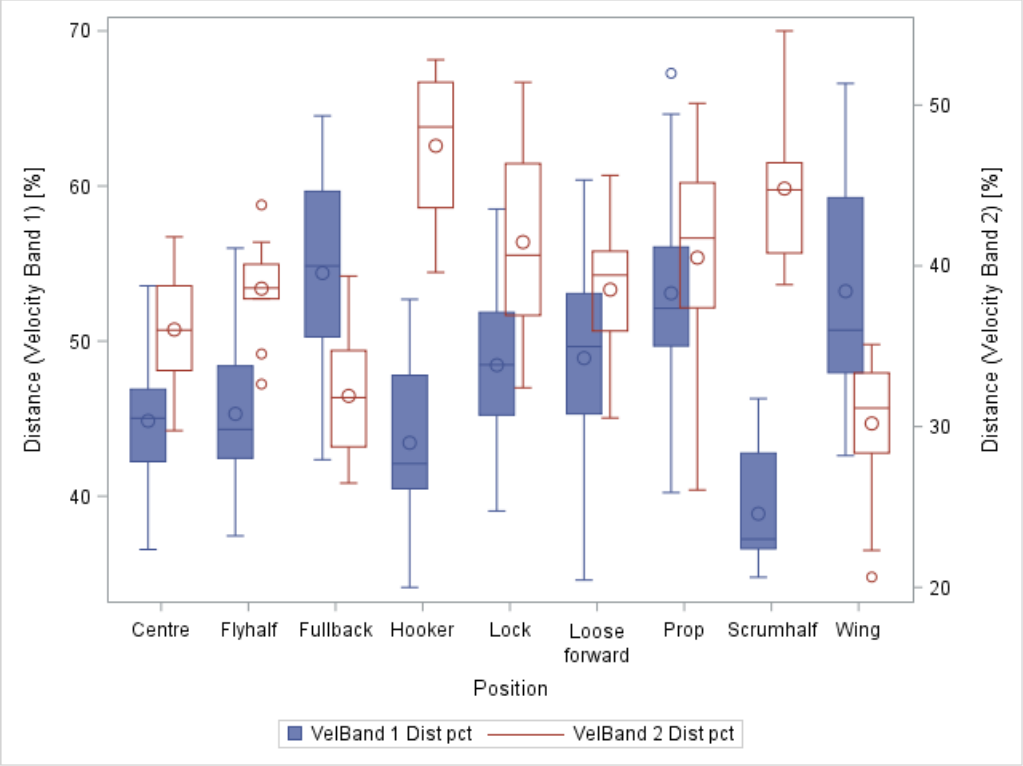

Figure 4.6. Box plot: Distance percentages Velocity band 1 & 2

Table 4.22. Velocity Band 1 Distance %: Statistical comparison of playing positions (pairwise P- values[a])

i/j	Centre	Flyhalf	Fullback	Hooker	Lock	Loose forward	Prop	Scrum half	Wing
Centre		0.805	<.0001	0.679	0.0424	0.0032	<.0001	0.0044	<.0001
Flyhalf	0.805		<.0001	0.5734	0.1482	0.0358	<.0001	0.007	<.0001
Fullback	<.0001	<.0001		<.0001	0.0009	0.002	0.4344	<.0001	0.3923
Hooker	0.679	0.5734	<.0001		0.0571	0.0128	<.0001	0.0516	<.0001
Lock	0.0424	0.1482	0.0009	0.0571		0.5154	0.002	<.0001	0.0023
Loose forward	0.0032	0.0358	0.002	0.0128	0.5154		0.0047	<.0001	0.0054
Prop	<.0001	<.0001	0.4344	<.0001	0.002	0.0047		<.0001	0.9356
Scrumhalf	0.0044	0.007	<.0001	0.0516	<.0001	<.0001	<.0001		<.0001
Wing	<.0001	<.0001	0.3923	<.0001	0.0023	0.0054	0.9356	<.0001	

[a]Pairwise P-values from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.

Table 4.23. Velocity Band 1 Distance %: Statistical comparison of playing positions (display of mean values and effect size)

Position	Mean[a]	Significance of pairwise comparison of playing positionb			Effect size	
					Partial ω²	$\omega = \sqrt{\omega^2}$
Fullback	54.61332			A	0.3912	0.63
Prop	53.093			A		
				A		
Wing	52.96479			A		
				A		
Loose forward	48.96718					
				B		
Lock	48.03086			B		
			C	B		
Flyhalf	45.30474		C			
			C			
Centre	44.8536		C			
			C			
Hooker	44.00129		C			
			C	D		
Scrumhalf	39.38039			D		
				D		

[a]Mean estimates and effect size statistic (for effect of playing position) from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.
[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.

4.3.3.3.2. Total distance percentages covered in velocity band 2

The td% mean value for all the players in VB2 was 38.1%. The highest mean values were achieved by the hooker 47.5%. The lowest mean value was by the wing 30.2%. Similarities can be seen by fullbacks 31.9% and wings 30.2% as the two lowest percentages in VB2. The loose forwards, locks, props and scrumhalf all had td% above 40%. This hooker had the highest td% in VB2. All players showed a high td% in VB2. Thus, all players covered high distances walking to jogging in VB2.

The results of the data for under-19 rugby players' VB2 td% covered during a match was also illustrated using boxplots. Figure 4.6 indicates according to the median that the highest td% in VB2 was by the hooker and the scrumhalf, while the lowest td% was by the wing and the fullback. Meaning that hookers and scrumhalf spent the most time jogging in VB2 compared to other positions. The wing and fullback had the lowest td%, walking and jogging the least amount of all players. The backline positions of flyhalf and centres had similar averages, while

the forward positions lock, loose forwards and props also had similar averages compared to that of these backline positions.

The hooker and locks had the largest IQR. Meaning that matches varied from one another. The smallest IQR was by the flyhalf, showing that from match to match there is little difference in distance covered in VB2. This was also noted in positions centre, wing and loose forwards.

The hooker had the highest median value and highest upper quartile value for td%. The scrumhalf and wings showed the lowest median values as well as the smallest lower quartile values for td%. Therefore, agreeing that hookers covered the highest distance during VB2. The wings and scrumhalf covered the lowest distances in VB2. This agrees with the descriptive statistics in Table 4.21.

Table 4.24 provides the pairwise p-values for td%, distances in in VB2. These values provide information on the statistical comparisons for the different player position in u/19 rugby. When comparing positions, the wing significant differences compared to all other positions $p<0.0001$, except for the of fullback which showed similar td%. The hooker showed significant difference compared to the centre, flyhalf, fullback, wings and loose forwards with $p<0.0001$ for td%. The hooker had the most time in the td% compared to other playing positions. The hooker was faster and more active than other positions in VB2. The wing was least active of all positions in VB 2.

Table 4.25 displays the mean values and effect size of the statistical comparisons between positions. The distances for VB2 confirm that the hookers had the highest td%. The wings had the lowest td%. The forwards all had similar values ranging from 38-41 td%, with exception of hooker. The effect size ($\omega=0.76$) was high in comparing different player positions.

Table 4.24. Velocity Band 2 Distance %: Statistical comparison of playing positions (pairwise P-valuesa)

i/j	Centre	Flyhalf	Fullback	Hooker	Lock	Loose forward	Prop	Scrum half	Wing
Centre		0.1183	0.0113	<.0001	<.0001	0.0479	0.0017	<.0001	<.0001
Flyhalf	0.1183		0.0005	<.0001	0.0706	0.938	0.2627	0.0025	<.0001
Fullback	0.0113	0.0005		<.0001	<.0001	<.0001	<.0001	<.0001	0.4014
Hooker	<.0001	<.0001	<.0001		0.0048	<.0001	0.0007	0.2423	<.0001
Lock	<.0001	0.0706	<.0001	0.0048		0.0146	0.4165	0.0952	<.0001
Loose forward	0.0479	0.938	<.0001	<.0001	0.0146		0.1207	0.0002	<.0001
Prop	0.0017	0.2627	<.0001	0.0007	0.4165	0.1207		0.0196	<.0001
Scrumhalf	<.0001	0.0025	<.0001	0.2423	0.0952	0.0002	0.0196		<.0001
Wing	<.0001	<.0001	0.4014	<.0001	<.0001	<.0001	<.0001	<.0001	

aPairwise P-values from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.

Table 4.25. Velocity band 2 Distance %: Statistical comparison of playing positions (display of mean values and effect size)

Variable	Position	Mean[a]	Significance of pairwise comparison of playing positionb			Effect size	
						Partial ω²	$\omega = \sqrt{\omega^2}$
Total distance [m]	Hooker	46.95917		A		0.5013	0.71
				A			
	Scrumhalf	44.50666	B	A			
			B				
	Lock	41.61522	B	C			
				C			
	Prop	40.45376	D	C			
			D	C			
	Flyhalf	38.58298	D	C	E		
			D		E		
	Loose forward	38.46355	D		E		
					E		
	Centre	36.03857			E		
	Fullback	31.73151		F			
				F			
	Wing	30.29647		F			

[aMean] estimates and effect size statistic (for effect of playing position) from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.
[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.

4.3.3.3.3. Total distance percentages covered in velocity band 3

The td% mean value for all the players in VB3 was 7.5%. The highest mean values were achieved by the scrumhalf 11.1% and the flyhalf 10.7%. The lowest mean value was by the props 4.7%. Similarities according to the means can be seen by the scrumhalf and flyhalf that had the highest td% of all players. The wing and fullback shared similar td% in backline players. The forward positions hooker and lock had similar td% values. The props had the lowest td% of all positions in VB3. Therefore, props td% when jogging to running was the smallest of all positions, while the scrumhalf and flyhalf hade highest jogging td%. It is notable that the td% was considerably lower for all positions than in VB 1 and 2.

The results of the data for under-19 rugby players' VB3 td% during a match was also illustrated using boxplots. Figure 4.7 indicates according to the median that the highest td% in VB3 was by the scrumhalf and the flyhalf, this is also true for the upper quartile range. While the lowest td% was by the prop and hooker, props having the lowest lower quartile range. This corresponds with the descriptive statistics for VB3 td%.

Meaning that the backline positions scrumhalf and flyhalf had higher td% than all other positions. Lowest td% was by props and loose forwards and locks shared similar td%. The wings and fullback shared similar td% as well that of forwards positions, the lock and loose forwards had a similar td%.

Table 4.26 provides the pairwise p-values for td%, distances covered in in VB3. These values provide information on the statistical comparisons for the different player position in u/19 rugby. When comparing positions, the scrumhalf and flyhalf had significant differences compared to all other positions $p<0.0001$, except for that of centres showed a lower td%. The props had the lowest td% significantly when compared to other positions. The loose forwards had the highest td% for all forwards. The scrumhalf and flyhalf was more active compared to other positions in VB 3, meaning these positions covered more distance and was faster than other positions in VB3. The props work the least in VB3 compared to all other positions, meaning that they were least active in VB3.

Table 4.27 displays the mean values and effect size of the statistical comparisons between positions. The td% for VB3 confirm that scrumhalf and flyhalf had the highest td%. The props had the lowest td%. The forwards all had similar values, with exception of loose forwards. The effect size ($\omega=0.69$) was high in comparing different player positions.

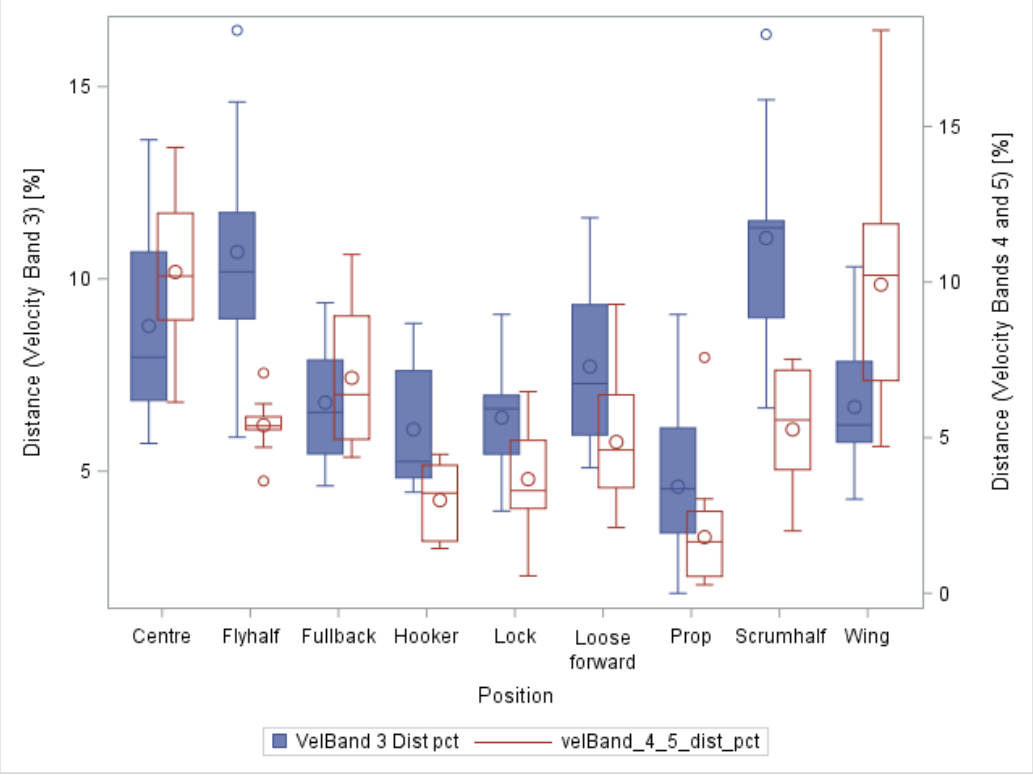

Figure 4.7. Box plot: Distance percentages velocity band 3, 4 and 5

Table 4.26. Velocity Band 3 Distance %: Statistical comparison of playing positions (pairwise P-valuesa)

i/j	Centre	Flyhalf	Fullback	Hooker	Lock	Loose forward	Prop	Scrum half	Wing
Centre		0.0042	0.0039	0.0004	0.0001	0.0346	<.0001	0.002	0.0003
Flyhalf	0.0042		<.0001	<.0001	<.0001	<.0001	<.0001	0.7601	<.0001
Fullback	0.0039	<.0001		0.3982	0.7284	0.1456	0.0026	<.0001	0.9673
Hooker	0.0004	<.0001	0.3982		0.5309	0.0204	0.0611	<.0001	0.3606
Lock	0.0001	<.0001	0.7284	0.5309		0.0232	0.0013	<.0001	0.7073
Loose forward	0.0346	<.0001	0.1456	0.0204	0.0232		<.0001	<.0001	0.0578
Prop	<.0001	<.0001	0.0026	0.0611	0.0013	<.0001		<.0001	0.0003
Scrumhalf	0.002	0.7601	<.0001	<.0001	<.0001	<.0001	<.0001		<.0001
Wing	0.0003	<.0001	0.9673	0.3606	0.7073	0.0578	0.0003	<.0001	

[a]Pairwise P-values from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.

Table 4.27. Velocity Band 3 Distance %: Statistical comparison of playing positions (display of mean values and effect size)

Position	Mean[a]	Significance of pairwise comparison of playing positionb		Effect size	
				Partial ω²	$\omega = \sqrt{\omega^2}$
Scrumhalf	10.94176		A	0.4825	0.69
			A		
Flyhalf	10.701718		A		
Centre	8.776223		B		
Loose forward	7.716128		C		
			C		
Fullback	6.764438	D	C		
		D	C		
Wing	6.735839	D	C		
		D			
Lock	6.519562	D			
		D			
Hooker	6.040788	D	E		
			E		
Prop	4.601575		E		

[a]Mean estimates and effect size statistic (for effect of playing position) from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.
[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.

4.3.3.3.4. Total distance percentages covered in velocity band 4 to 5

The td% mean value for all the players in VB4 was 3.8% and VB5 2.1%. The highest mean values of td% in VB4 was by the centres 6.2% and the wing 4.9%, while in VB5 wings had higher td% of 5% and centres a lower td% of 4.1%. The lowest mean value in VB4 was by the props 1.4% while in VB5 props 0.4%, forwards all had very low td%, loose forwards had the highest td% of all forwards.

Similarities in VB4 according to the means, it shows that centres had the highest td%. Props had the lowest td%. Loose forwards had the highest td% of all forward positions. Similarities in VB5 backline players wings and centres had the highest td% at5% for wings and 4.1% for centres. Similarities in both VB 4and 5 according to the means, it shows that all forward positions had a much lower td%, than backline positions, with props lowest of all. Although when comparing td% of a match, VB 4 and 5 was extreme low in comparison with that of VB1,2 and 3 for all positions.

The results of the data for under-19 rugby players' VB 4 and 5 td% during a match was also illustrated using boxplots. Figure 4.7 indicates according to the median that the highest td% in VB 4 and 5 centres and the wings, this is also true for the upper quartile range. While the lowest td% was by the prop and forward positions in general had a very low td%. This corresponds with the descriptive statistics for VB 4 and 5. Meaning that the backline positions centre and wings had higher td% than all other positions. Lowest td% was by props and forwards who shared similar td%. The hooker, lock and scrumhalf shared similar td%.

Table 4.28 provides the pairwise p-values for distances covered in in VB 4 and 5. These values provide information on the statistical comparisons for the different player position in u/19 rugby. When comparing positions, the centre and wings had significant differences compared to all other positions $p<0.0001$. The wings and centres were the fastest players in the team, covering the highest td% than other positions, with centres being the fastest in VB4 and wings te fastest of all positions in VB5. The props had the lowest td% significantly when compared to other positions, meaning that the props were slowest of all players and showed very low td% compared to all other positions in VB4 and 5.

Table 4.29 displays the mean values and effect size of the statistical comparisons between positions. The td% for VB 4 and 5 confirm that centres and wings had the highest td%. The props had the lowest td%. The forwards all had lower td% values, with exception of loose

forwards being the highest of the forwards. The effect size (ω=0.83) was high in comparing different player positions.

Table 4.28. Velocity Band 4 - 5 Distance %: Statistical comparison of playing positions (pairwise P- values[a])

i/j	Centre	Flyhalf	Fullback	Hooker	Lock	Loose forward	Prop	Scrum half	Wing
Centre		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.5886
Flyhalf	<.0001		0.081	0.0083	0.0329	0.4129	<.0001	0.7771	<.0001
Fullback	<.0001	0.081		<.0001	<.0001	0.0042	<.0001	0.0486	<.0001
Hooker	<.0001	0.0083	<.0001		0.3076	0.0166	0.1624	0.0192	<.0001
Lock	<.0001	0.0329	<.0001	0.3076		0.07	0.0019	0.0794	<.0001
Loose forward	<.0001	0.4129	0.0042	0.0166	0.07		<.0001	0.6546	<.0001
Prop	<.0001	<.0001	<.0001	0.1624	0.0019	<.0001		<.0001	<.0001
Scrumhalf	<.0001	0.7771	0.0486	0.0192	0.0794	0.6546	<.0001		<.0001
Wing	0.5886	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	

[a]Pairwise P-values from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.

Table 4.29. Velocity band 4 - 5 Distance %: Statistical comparison of playing positions (display of mean values and effect size)

Position	Mean[a]	Significance of pairwise comparison of playing position[b]		Effect size	
				Partial ω²	$\omega = \sqrt{\omega^2}$
Centre	10.324017		A	0.6904	0.83
			A		
Wing	10.000908		A		
Fullback	6.884073		B		
			B		
Flyhalf	5.402036	C	B		
		C			
Scrumhalf	5.16297	C	D		
		C	D		
Loose forward	4.849105	C	D		
			D		
Lock	3.826763	E	D		
		E			
Hooker	2.988189	E	F		
			F		
Prop	1.838319		F		

[a]Mean estimates and effect size statistic (for effect of playing position) from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.
[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.

4.3.3.4. Duration in velocity bands

4.3.3.4.1. Total duration

The Table 4.30 provides data for the descriptive statistics of the total duration (Td) measured in minutes (min) and seconds (s) spent in velocity bands (VB) 1 to 5 for all the different playing positions in u/19 rugby. The number (N) of players tested by GPS technology was 149. The boxplot in Figure 4.8 provides information on VB1 and 2 for Td. Figure 4.9 provides information on VB3 to 5 for the distribution of data for the Td. The average mean values for Td in each velocity band (VB) can be classified for VB 1 - 5.

Table 4.30. Velocity Bands: Duration [s]: Descriptive statistics

Variable		Position name									
		Centre	Flyhalf	Fullback	Hooker	Lock	Loose forward	Prop	Scrum half	Wing	All
	N	21	11	10	8	19	32	18	10	20	149
Velocity Band 1 Total Duration [s]	Mean	59.5	59.8	61.5	58.7	59.9	60.2	60.6	58.4	62.5	60.3
	Min	54.2	55.7	55.7	52.9	54	55.3	51.7	55.1	55.6	51.7
	Median	58.1	58.5	61.7	55.7	58.9	58.5	60.2	57.3	60.9	59.1
	Max	72.4	73.1	71.6	69.4	71.7	73.9	77.7	65.8	75.9	77.7
Velocity Band 2 Total Duration [s]	Mean	12	12	11	15	13.3	12.3	13	14.2	9.6	12.3
	Min	7.8	8	6.9	10.4	9.9	7.4	6.6	10.3	5.9	5.9
	Median	12.2	11.9	10.8	15.7	12.3	12.2	13.7	14.2	9.5	12.1
	Max	14.4	14.6	15.2	17.8	17.5	16.5	18.2	19	13.2	19
Velocity Band 3 Total Duration [s]	Mean	1.7	2.1	1.4	1.2	1.2	1.5	0.9	2.2	1.3	1.4
	Min	0.9	1.3	1	0.8	0.6	0.9	0.3	1.2	0.9	0.3
	Median	1.6	2	1.2	1.1	1.3	1.4	0.8	2.1	1.2	1.3
	Max	3.1	3.5	2.3	1.9	2.1	2.6	2	3.5	2.1	3.5
Velocity Band 4 Total Duration [s]	Mean	1	0.5	0.7	0.3	0.4	0.6	0.2	0.6	0.7	0.6
	Min	0.5	0.4	0.4	0.2	0.1	0.2	0	0.3	0.3	0
	Median	1	0.6	0.6	0.3	0.4	0.5	0.2	0.6	0.7	0.6
	Max	1.5	0.8	1.1	0.5	0.8	1.2	0.7	1.1	1.3	1.5
Velocity Band 5 Total Duration [s]	Mean	0.5	0.2	0.4	0.1	0.1	0.1	0	0.2	0.6	0.3
	Min	0.2	0.1	0.1	0	0	0	0	0	0.2	0
	Median	0.5	0.2	0.3	0.1	0.1	0.1	0	0.1	0.6	0.2
	Max	0.9	0.5	0.8	0.2	0.4	0.6	0.5	0.4	1.2	1.2
Velocity Band 3-5 Total Duration [s]	Mean	3.2	2.8	2.4	1.6	1.8	2.2	1.1	2.9	2.6	2.3
	Min	2	1.8	1.5	1.1	0.8	1.3	0.3	1.7	1.7	0.3
	Median	3	2.8	2.3	1.5	1.8	2	1	2.8	2.5	2.2
	Max	4.6	4.6	3.5	2.5	3	3.9	3.2	4.8	4.1	4.8

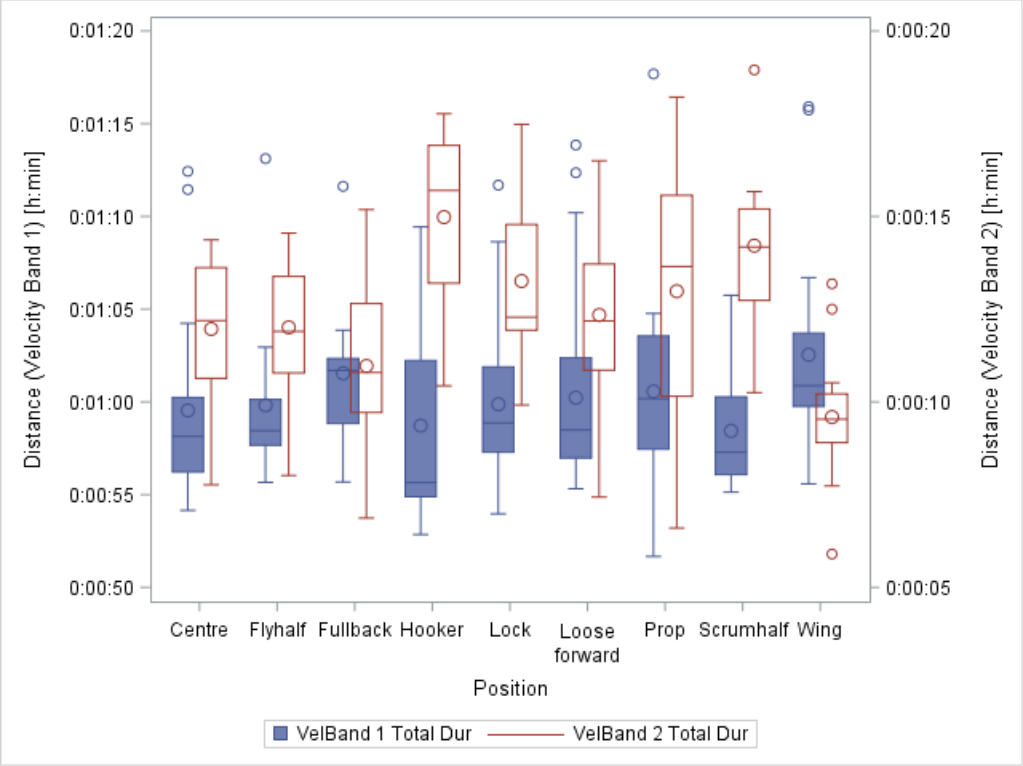

Figure 4.8. Box plot: Durations for Velocity band 1 and 2

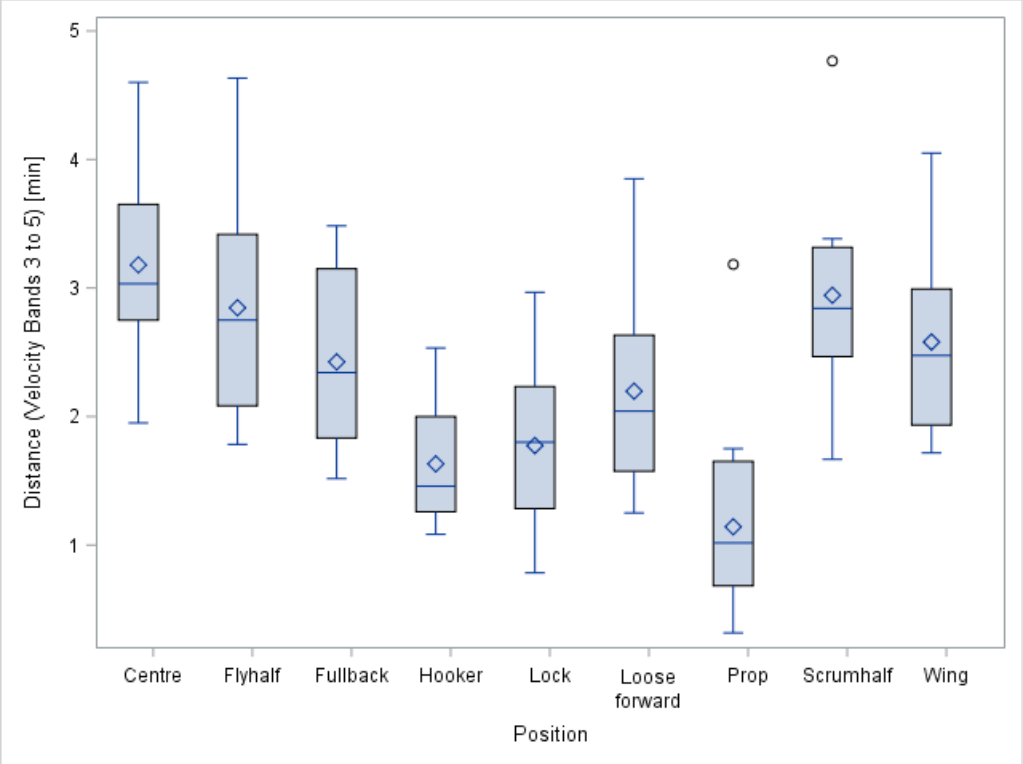

Figure 4.9. Box plot: Durations for Velocity band 3, 4 and 5

4.3.3.4.1.1. Total duration in velocity band 1

The Td mean value for all the players in VB1 was 60.3 min. The highest mean values were achieved by the wings 62.5 min, followed by fullback and centres. The lowest mean value was by the scrumhalf 58.4 min. All positions had a Td above 60 min.

The results of the data for under-19 rugby players' VB1 covered during a game were also illustrated using boxplots. Figure 4.8 indicates that all players had a relatively high Td. The IQR was higher for hookers and props than that of other positions, meaning that durations varied from match to match.

Fullbacks and wings had higher durations according to the median lines, the hooker and scrumhalf had the lowest Td according to the median and lower quartile range. The prop and the wing had the highest upper quartile range Td. The most time spent in VB1 was by the backline positions of fullback and wings.

Table 4.31 provides the pairwise p-values for td% in VB1. These values provide information on the statistical comparisons for the different player position in u/19 rugby. When comparing positions, the wing spent more time in VB1 compared to all other positions, except for that of the full back position. Wings and full back significantly differed from that of the centre, hooker and scrumhalf all showed significant differences to one another $p<0.0001$.

All positions had a similar mean value, with the highest duration for wing and the lowest for scrumhalf. When comparing all positions, all players had a relatively high Td in VB1. Meaning that all players spent he most time standing or walking in a rugby match.

Table 4.32 displays the mean values and effect size of the statistical comparisons between positions. The VB1 confirm that wing and fullback had the highest Td of all positions. The scrumhalf and hooker had the lowest Td. Props had the highest Td amongst forward positions. Although, all positions had a relatively similar and high duration in VB1. The effect size ($\omega=0.43$) was significant in comparing different player positions.

Table 4.31. Velocity Band 1 Duration: Statistical comparison of playing positions (pairwise P- values[a])

i/j	Centre	Flyhalf	Fullback	Hooker	Lock	Loose forward	Prop	Scrum half	Wing
Centre		0.7422	0.0748	0.1503	0.9003	0.247	0.0725	0.0662	<.0001
Flyhalf	0.7422		0.1913	0.1233	0.8348	0.5672	0.2371	0.0602	0.0023
Fullback	0.0748	0.1913		0.0087	0.1081	0.3025	0.7384	0.0024	0.1564
Hooker	0.1503	0.1233	0.0087		0.1396	0.0249	0.0082	0.8823	<.0001
Lock	0.9003	0.8348	0.1081	0.1396		0.3524	0.1171	0.0641	0.0002
Loose forward	0.247	0.5672	0.3025	0.0249	0.3524		0.3906	0.0053	0.0009
Prop	0.0725	0.2371	0.7384	0.0082	0.1171	0.3906		0.0015	0.03
Scrumhalf	0.0662	0.0602	0.0024	0.8823	0.0641	0.0053	0.0015		<.0001
Wing	<.0001	0.0023	0.1564	<.0001	0.0002	0.0009	0.03	<.0001	

[a]Pairwise P-values from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.

Table 4.32. Velocity Band 1 Total Duration: Statistical comparison of playing positions (display of mean values and effect size)

Position	Mean[a]	Significance of pairwise comparison of playing positionb		Effect size	
				Partial ω²	$\omega = \sqrt{\omega^2}$
Wing	62.43411		A	0,1882	0.43
			A		
Fullback	61.1422	B	A		
		B			
Prop	60.83414	B			
		B			
Loose forward	60.26291	B			
		B			
Flyhalf	59.81364	B	C		
		B	C		
Lock	59.63201	B	C		
		B	C		
Centre	59.54091	B	C		
			C		
Hooker	58.11821		C		
			C		
Scrumhalf	57.95333		C		

[a]Mean estimates and effect size statistic (for effect of playing position) from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.
[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.

4.3.3.4.1.2. Total duration in velocity band 2

The Td mean value for all the players in VB2 was 12.3 min. The highest mean values were achieved by the hooker 15 min and the scrumhalf 14.2 min. The lowest mean value was by the wing 9.6 min. Similarities can be seen by centres, flyhalf and fullbacks for Td in VB2. The loose forwards, locks, props all had similar Td. All players showed a high Td in VB2. Thus, all players spending time covered high distances walking to jogging in VB2.

The results of the data for under-19 rugby players' VB2 Td covered during a match was also illustrated using boxplots. Figure 4.8 indicates according to the median that the highest Td in VB2 was by the hooker and the scrumhalf, while the lowest Td was by the wing. Meaning that hookers and scrumhalf spent the most time jogging in VB2 compared to other positions. The wing had the lowest Td, walking and jogging the least amount of all players.

The props had the largest IQR. Meaning that matches varied from one another. The smallest IQR was by the wings, showing that from match to match there is little difference in distance covered in VB2. The hooker and scrumhalf had the highest median value and highest upper quartile value for Td. These positions spent the most time in VB2. The wings spent the lowest time in VB2 of positions. This agrees with the descriptive statistics for VB2.

Table 4.33 provides the pairwise p-values for Td, time spent in VB2. These values provide information on the statistical comparisons for the different player position in u/19 rugby. When comparing positions, the wing significant differences compared to all forward positions and the scrum half $p<0.0001$. The of fullback which showed similar Td to that of the wing Td. The full back and wing had much lower durations in VB 2 than other positions, while hooker, lock and spent more time running in VB2. Thus, the wings were had lower running activity than all other positions.

Table 4.34 displays the mean values and effect size of the statistical comparisons between positions. In forward positions, locks, props, loose forwards all had similar values of around 12 to 13 min. The hooker had the highest Td in VB2. Flyhalf, centre and fullback had similar durations between 10.8 min to 12.3 min for Td. The wings had the lowest duration of 9.6 min. The effect size ($\omega=0.52$) was significant in comparing different player positions.

Table 4.33. Velocity Band 2 Duration: Statistical comparison of playing positions (pairwise P-values)

i/j	Centre	Flyhalf	Fullback	Hooker	Lock	Loose forward	Prop	Scrum half	Wing
Centre		0.9528	0.1511	0.0024	0.0323	0.5397	0.1553	0.012	0.0002
Flyhalf	0.9528		0.192	0.0078	0.0856	0.6718	0.2628	0.0315	0.0019
Fullback	0.1511	0.192		0.0002	0.0021	0.0485	0.0119	0.0009	0.1168
Hooker	0.0024	0.0078	0.0002		0.1558	0.0058	0.0509	0.5129	<.0001
Lock	0.0323	0.0856	0.0021	0.1558		0.0824	0.4796	0.4547	<.0001
Loose forward	0.5397	0.6718	0.0485	0.0058	0.0824		0.3402	0.0288	<.0001
Prop	0.1553	0.2628	0.0119	0.0509	0.4796	0.3402		0.1823	<.0001
Scrumhalf	0.012	0.0315	0.0009	0.5129	0.4547	0.0288	0.1823		<.0001
Wing	0.0002	0.0019	0.1168	<.0001	<.0001	<.0001	<.0001	<.0001	

[aPairwise] P-values from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.

Table 4.34. Velocity Band 2 Total Duration: Statistical comparison of playing positions (display of mean values and effect size)

Variable	Position	Mean[a]	Significance of pairwise comparison of playing positionb			Effect size	
						Partial ω²	$\omega = \sqrt{\omega^2}$
Total distance [m]	Hooker	14.544135		A		0.2693	0.52
				A			
	Scrumhalf	13.917045		A			
				A			
	Lock	13.326395	B	A			
			B	A			
	Prop	12.863878	B	A	C		
			B		C		
	Loose forward	12.305449	B		C		
			B		C		
	Flyhalf	12.007576	B	D	C		
				D	C		
	Centre	11.963636		D	C		
				D			
	Fullback	10.855769	E	D			
				E			
	Wing	9.623829	E				

[aMean] estimates and effect size statistic (for effect of playing position) from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.
[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.

4.3.3.4.1.3. Total duration in velocity band 3 to 5

The Td mean value for all the players in VB3 was 1.4 min, VB4 was 0.6 min and VB5 0.3 min. Combined total of 2.3 min. VB3 to 5 in comparison with VB 1 and 2 was significantly small for a 75 minutes match. Backline players had highest durations compared to forwards. Centres totaling 3.2 min and scrumhalf 2.9 min. Forwards did not have any relevant time in VB 4 and 5.

The highest mean values of Td in VB3 was by the scrumhalf and flyhalf. The wings, fullbacks and centres had similar values. Props had smallest values of 0.9 min. The lock and hooker position had similar Td. The Td for VB4 made up only 1 min of the playing time. The highest mean values for Td in VB4 centres 1 min, followed by the wings and all backline players. Loose forwards had the only relevant Td for forwards in VB4. The average mean for all players was 0.6 min, which is significantly small to the Td of a match of 75 min. High intensities of running are characteristics of VB4. The Td for VB5 showed that wings 0.6 min had the highest mean values, followed by centres 0.5 min. Props had a 0 min value, meaning they did not spend time VB5. Other forward positions had a mean of 0.1 min, which suggests speeds are very low in VB5 for forwards or nonexistent.

The results of the data for under-19 rugby players' VB 3, 4 and 5 Td during a match was also illustrated using boxplots. Figure 4.9 indicates according to the median that the centre had the highest duration, followed by scrumhalf, flyhalf and wings. This confirms that backline players spent the most time in VB3 to 5 compared to that of forwards in VB3 to 5. The props had the lowest Td of all players and the loose forwards had the highest of all forwards. The whiskers show that the centre and flyhalf had the highest Td in VB 3 to 5. The IQR showed that the flyhalf and fullback had the greater variations from match to match than other positions.

Table 4.35 provides the pairwise p-values for Td, Td in VB 3, 4 and 5. These values provide information on the statistical comparisons for the different player position in u/19 rugby. When comparing positions, the backs showed the highest durations in VB 3-5 with the centre having the highest duration for VB 3-5, followed by the scrum half and flyhalf which showed similar durations in VB 3-5. Thus, in VB 3-5 backs were more active compared to that of forward groupings. Showed significant differences compared to all other forward positions $p<0.0001$, although similarities can be found in backline positions. Scrum half, fly half and centres differed from the forward positions of hooker and lock $p< 0.0001$.

Table 4.36 displays the mean values and effect size of the statistical comparisons between positions. All the backline players had the highest Td in Vb3 to 5. The loose forwards had the highest Td of all forwards of 2.19 min. The props time of 1.2 min was the lowest Td of all players. The effect size (ω=0.72) was high in comparing different player positions.

Table 4.35. Velocity Band 3 - 5 Duration: Statistical comparison of playing positions (pairwise P-valuesa)

i/j	Centre	Flyhalf	Fullback	Hooker	Lock	Loose forward	Prop	Scrum half	Wing
Centre		0.1251	0.0008	<.0001	<.0001	<.0001	<.0001	0.1632	0.0019
Flyhalf	0.1251		0.0928	<.0001	<.0001	0.0018	<.0001	0.9385	0.2764
Fullback	0.0008	0.0928		0.0034	0.0121	0.3059	<.0001	0.0867	0.3972
Hooker	<.0001	<.0001	0.0034		0.3227	0.0095	0.0723	<.0001	<.0001
Lock	<.0001	<.0001	0.0121	0.3227		0.0332	0.0004	<.0001	<.0001
Loose forward	<.0001	0.0018	0.3059	0.0095	0.0332		<.0001	0.002	0.0152
Prop	<.0001	<.0001	<.0001	0.0723	0.0004	<.0001		<.0001	<.0001
Scrumhalf	0.1632	0.9385	0.0867	<.0001	<.0001	0.002	<.0001		0.255
Wing	0.0019	0.2764	0.3972	<.0001	<.0001	0.0152	<.0001	0.255	

[a]Pairwise P-values from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.

Table 4.36. Velocity Band 3 - 5 Total Duration: Statistical comparison of playing positions (display of mean values and effect size)

Position	Mean[a]	Significance of pairwise comparison of playing positions		Effect size	
				Partial ω²	$\omega = \sqrt{\omega^2}$
Centre	3.1795455		A	0.5251	0.72
			A		
Scrumhalf	2.8652941	B	A		
		B	A		
Flyhalf	2.8454545	B	A		
		B			
Wing	2.6046978	B			
		B			
Fullback	2.4110826	B	C		
			C		
Loose forward	2.1925258		C		
Lock	1.8258715		D		
			D		
Hooker	1.5785046	E	D		
		E			
Prop	1.1270296	E			

[a]Mean estimates and effect size statistic (for effect of playing position) from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.
[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.

4.3.3.5. Velocity

4.3.3.5.1. Maximum velocities

The data in Table 4.37 provides information on the mean maximum velocity (MV) achieved by the different player positions in under-19 rugby measured as metre per second ($m.s^{-1}$). The average mean MV value for all positions achieved was 8.3 $m.s^{-1}$. The highest mean MV was achieved by the position wing 9.45 $m.s^{-1}$. The minimum MV achieved was by the props at 7.06 $m.s^{-1}$. The fullback (8.86 $m.s^{-1}$), flyhalf (8.72 $m.s^{-1}$) and scrumhalf (8.25 $m.s^{-1}$) achieved above 8 $m.s^{-1}$. It is notable that the top MV achieved were by backline players. The highest MV achieved by a forward was by loose forwards at 7.97 $m.s^{-1}$ followed by hooker (7.75 $m.s^{-1}$) and lock (7.7 $m.s^{-1}$) and props.

The highest MV achieved during a player in a single match over a period of 11 matches was by a backline player, the wing achieved 10.43 $m.s^{-1}$. The centre had the second highest MV at 9.72 $m.s^{-1}$. The forward position with the highest MV was achieved by the loose forwards 9.12 $m.s^{-1}$. The scrumhalf achieved 9.1 $m.s^{-1}$.

The results of the data for under-19 rugby players' regarding MV were also illustrated using boxplots. Figure 4.10 illustrates according to the median (middle line) the highest MV was achieved by wings, followed by centres, flyhalf and fullback respectively. These are all backline playing positions. The smallest MV achieved was by props.

The IQR was highest in locks which reveals that MV differ match to match. It was smallest in wings and fullback, which reveals that these backline positions relatively the same from match to match. The upper quartile reveals the MV was achieved by the wings (backline), this show that wings are significantly faster than all other positions. The whiskers are in agreement that wings are the fastest players in a match. The centres achieved the second highest upper quartile value and the whiskers are agreement. The lower quartile reveals that the lowest MV was achieved by props (forwards). The whiskers show that is true. These values correspond with Table 4.37 for MV during u/19 rugby match.

Table 4.37. Maximum Velocity [m.s⁻¹]: Descriptive statistics

Variable		Position name									All
		Centre	Flyhalf	Fullback	Hooker	Lock	Loose forward	Prop	Scrum half	Wing	
	N	21	11	10	8	19	32	18	10	20	149
Maximum Velocity [m.s⁻¹]	Mean	9.07	8.72	8.86	7.75	7.7	7.97	7.06	8.25	9.45	8.3
	Min	8.24	7.88	7.74	7.05	6.7	7.07	5.94	6.7	8.57	5.94
	Median	9.19	8.8	9.04	7.77	7.74	7.98	6.91	8.38	9.41	8.38
	Max	9.72	9.46	9.21	8.54	8.85	9.12	8.61	9.1	10.43	10.43

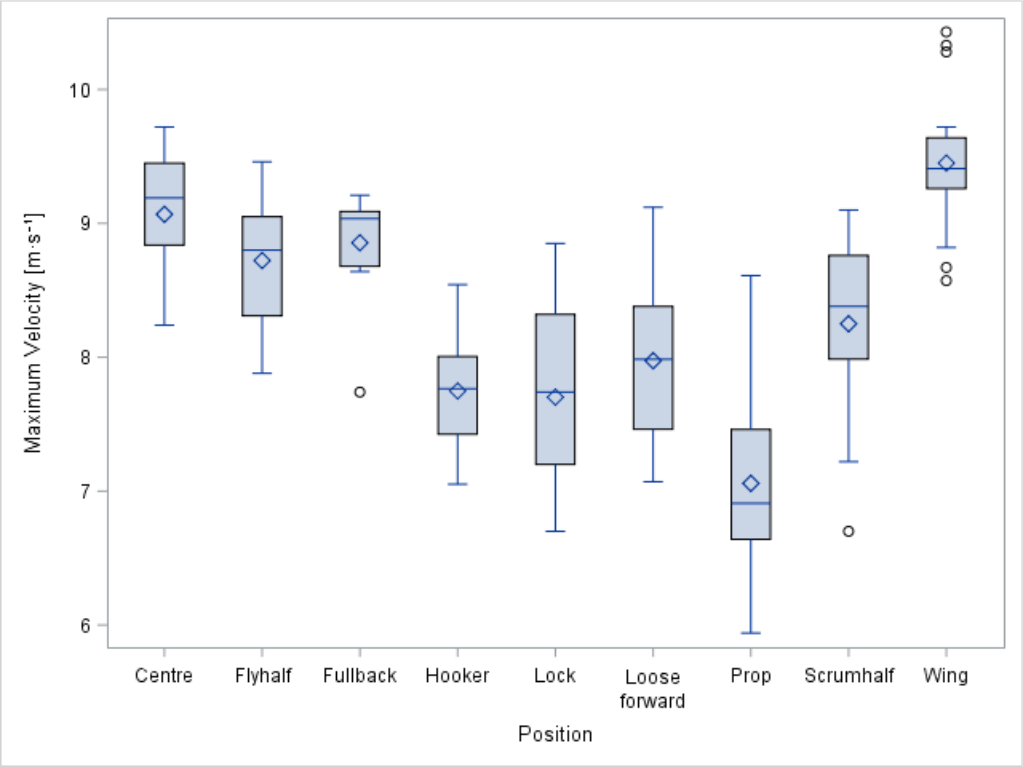

Figure 4.10. Box plot: Maximum Velocity [m.s⁻¹]

The Table 4.38 provides the pairwise p-values for MV. These values provide information on the statistical comparisons for the different player position in u/19 rugby.

When comparing positions, the centres and wings showed the significant differences compared to all forward positions in MV ($p<0.001$). Forwards and backs had significant

differences comparing the positional groups. The scrumhalf and flyhalf revealed similar MV. It is notable that backline players all achieved the highest MV between backline and forward positions. In the forwards, the lock and hooker had similar MV, props were the least comparable to other positions. This correlates with props achieving the slowest MV, being the slowest positions in rugby revealed in Table 4.37.

Table 4.39 displays the mean values and effect size of the statistical comparisons between positions. The player with the highest MV was wings, followed by centre, fullback, flyhalf and scrumhalf all backline players. The MV achieved by forwards was achieved by the loose forwards, followed by the hookers and locks which achieved similar MV to one another. The props achieved the lowest MV for all player positions. The effect size (ω=0.79) was relatively high in comparing different player positions.

Table 4.38. Maximum Velocity: Statistical comparison of playing positions (pairwise P-valuesa)

i/j	Centre	Flyhalf	Fullback	Hooker	Lock	Loose forward	Prop	Scrum half	Wing
Centre		0.1086	0.3422	<.0001	<.0001	<.0001	<.0001	0.0002	0.0375
Flyhalf	0.1086		0.592	0.0004	<.0001	0.0003	<.0001	0.0518	0.001
Fullback	0.3422	0.592		<.0001	<.0001	<.0001	<.0001	0.0162	0.0094
Hooker	<.0001	0.0004	<.0001		0.901	0.3026	0.0064	0.0771	<.0001
Lock	<.0001	<.0001	<.0001	0.901		0.112	0.0008	0.0232	<.0001
Loose forward	<.0001	0.0003	<.0001	0.3026	0.112		<.0001	0.2317	<.0001
Prop	<.0001	<.0001	<.0001	0.0064	0.0008	<.0001		<.0001	<.0001
Scrumhalf	0.0002	0.0518	0.0162	0.0771	0.0232	0.2317	<.0001		<.0001
Wing	0.0375	0.001	0.0094	<.0001	<.0001	<.0001	<.0001	<.0001	

aPairwise P-values from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.

Table 4.39. Maximum Velocity: Statistical comparison of playing positions (display of mean values and effect size)

Variable	Position	Mean[a]	Significance of pairwise comparison of playing positionb		Effect size	
					Partial ω²	$\omega = \sqrt{\omega^2}$
Total distance [m]	Wing	9.4488436		A	0.6222	0.79
	Centre	9.0689723		B		
				B		
	Fullback	8.8576418		B		
				B		
	Flyhalf	8.722	C	B		
			C			
	Scrumhalf	8.2264744	C	D		
				D		
	Loose forward	7.9746381	E	D		
			E	D		
	Hooker	7.7369504	E	D		
			E			
	Lock	7.7063849	E			
	Prop	7.0511117		F		

[a]Mean estimates and effect size statistic (for effect of playing position) from two-way analysis of variance (ANOVA) model with playing position and match as fixed effects.
[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.

The results of the study revealed that in 11 rugby matches that were played in 2019 the following physical demands were assessed for the physical profile of under-19 rugby players: Total player load (TPL) and TPL per metre showed that forwards experienced higher intensities and work rate than that of backline players, with an average mean of 583.7 (au) for all positions. Total distance covered showed that backs achieved higher distances than forwards, fullbacks achieving highest distances, props covered lowest distances, the average mean for all players was 5733.5m. Total distance percentages showed that the higher distance percentages were found in VB1 and 2, while shorter distance percentages were seen in VB3-5. Wings were the fastest followed by centres, and VB 3 showed that forwards were most active. Total duration showed that most time spent in a match was standing to walking. One can make the conclusion that lower distance in VB3-5 was meant that higher velocities in these distances were achieved, and that lower velocities are associated with VB1 and VB2. Maximum velocity showed that z mean average of 8.3 $m.s^{-1}$ for all players. Backline players achieved highest velocities. These were the results of under-19 rugby level in 2019.

CHAPTER 5
DICUSSION OF THE RESULTS

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

5.1 Introduction

The study is one of the first of its kind in South Africa monitoring TMA through GPS technology to measure the physical demands: total player load, total player load per metre, distance covered, total distance percentage in velocity bands 1-5, total duration in velocity bands 1-5, and the maximum velocity of under-19 rugby players at school level. The secondary aim was to compare positional groups of forwards and backs according to the physical demands in the primary aims of the study. According to the researcher, until today there has been little research done on these physical demands placed on under-19 rugby players at first team rugby at school level in South Africa.

Interestingly though, the developments in rugby through coaching techniques as well as the strength and conditioning of players to improve fitness levels have greatly improved in the last decade across all ages of rugby. Coaching and conditioning at under-19 level in schools has dramatically changed and improved. Schools now compete yearly at even higher levels, as teams enjoy TV coverage for matches and are continually under the spotlight, when it comes to the performance of 1st team rugby in South Africa. These under-19 rugby teams are the feeder system for senior professional rugby in South Africa.

To establish the true physical and physiological demands of under-19 rugby, the researcher measured five primary objectives that were successfully monitored using the Catapult Mini Max X4 system. The GPS system has been proven accurate and reliable by various research articles written for assessing TMA in sport. These five objectives were to discover the total player load and player load per metre, total distance covered during a match, the total distance percentage compared in velocity bands 1 – 5, duration compared for each velocity band, and the maximum velocity by all position in under-19 rugby. These findings were assessed and comparisons follow in the discussion of the results.

The data provided for TMA by GPS technology has established values that reflect the physical profile for each under-19 position and it is now possible to statistically compare different rugby positions at under-19 level, for example the forward physical profile compared to that of the backs during match-play. Due to the professional nature of sport, rugby coaches as well as strength and conditioning specialists are in suit of the physical profiles of under-19 rugby players, which provide guidelines for the strength conditioning and rugby coaching sessions relevant to match-play at under-19 level.

The study successfully monitored 11 rugby matches during the 2019 rugby season, that began in March and ended in August 2019. Two warm-up matches served as a pilot study, which was not included in the data. The number of participations that were monitored during the study was relatively high n = 151 in Table 4.1. From this data provided the descriptive statistics for player positions and comparisons were made.

5.2 Player Load

5.2.1 Total player load

To determine physical profile of players, the Catapult Minimax X4 accelerometer unit measures accelerations in the frontal-, sagittal- and transverse axes of movement to determine a variable called player load (PL) (Gabbett, 2012). Chandler *et al.* (2014) described the PL as a measure of physical activity by measuring the accumulation of accelerations in all 3 planes of movement (frontal, sagittal and transverse).

The results for TMA through GPS technology using the Catapult Mini X4 system provided the following data in terms of total player load (TPL) and total player load per metre. This data was completed in the 2019 rugby season and consisted of 11 rugby matches. The descriptive statics for TPL for all the player positions are shown in Table 4.1 TPL.

TPL indicates how physically intense a player may experience a match. Due to different positional requirements and the nature of rugby, differences in TPL can be expected. The TPL of under-19 rugby revealed that the forwards experienced higher TPL than that of backline positions, which is expected and makes sense when coaches look at the nature of the game. The real question is which players experience the game more physically than others, as well as which players amongst forwards was the physically hardest working positions in match-play. According to table 4.1 the locks (636.4 PL (au)) mean value revealed the highest levels amongst all players, this can be due to the positional play of locks, having to do the most physical work, where it be taking the ball up in ball carries or working defensively through tackling and rucking. The props (603.3 PL (au)) experienced high physical demands due to the scrummaging and mauling aspects of their position, while the lose forwards (600 PL (au)) also showed similar TPL according to the mean. Notably all these players are forward positions.

As expected the TPL of forward positions were higher than that of back positions, showing that the game of rugby is more physical for forwards when comparing forwards and backs. The locks proved to be the hardest workers in the team followed by the props. Interestingly

the hooker showed the lowest TPL in all forward positions. This can be due to the nature of the game, where hookers are more involved in higher distance running activities than that of other forward positions. Forward positions also showed that according to the TPL, similar work rates and exertions were experienced by locks, props and loose forwards. These players experienced higher levels of physical exertion.

The positions that experienced lower similar TPL values when comparing the means of Table 4.1 were the flyhalf (541.7 PL(au)), wings (526.1 PL(au)) and fullback (556.8 PL (au)) playing positions. Notably these positions are all backline players. When comparing the average TPL of rugby players the forwards seemed to experience the highest TPL and the backline positions the lower TPL. The locks experienced highest TPL levels of all players, meaning that they had the highest physical demands of any player, probably due to the nature of the position being physically more involved in the game than any other rugby player, although all forwards showed higher TPL than that of backline players. Further studies done at u/19 level will be able to provide more values in comparing TPL, as little research on TPL at under-19 level is available in South Africa.

The forwards had the highest TPL, with lock dominating the physical aspect of the game. The scrum half showed the highest TPL of backline players, centres had similar TPL to that of the scrumhalf. In forwards position, the hooker had the lowest TPL during match-play, however hookers covered higher distances than other forwards. Similar TPL values exist for forwards and require high demands of fitness and strength when partaking in match-play. The backline players, wings and fullback had lower TPL, this is most probably due to the lower levels of physical contact during match-play and higher demands placed on maximal sprinting that is part of the positional nature of wings. The backline players require higher speeds that can be seen in the maximum velocities of players.

Interestingly, the maximum TPL experienced by a player in a single match over a period of 11 matches was by the forward position of locks (877.4 Player Load™ (au)), followed by scrum half (834.5 PL(au)) and props (832.1 PL(au)). The position props experienced a wider variation of TPL where levels of intensity differed from match to match. The minimum total player load was experienced by props (377.5 PL(au)) followed by wings (412 PL (au)). This could be due to substitution or the nature of the game. This confirms that forwards experienced the most TPL of under-19 rugby players. Matches can be dominated by either forward or backline coaching tactics which alter the physical intensity of the game. Tactics that involve predominantly forwards will logically show higher TPL than those tactics used in a wide

running game where backline players are predominantly involved. Coaches often use such techniques when competing in rugby.

5.2.2 Total player load per metre

The TPL per metre showed similar results when compared to TPL. The data in Table 4.4 shows that the mean TPL per metre for all positions in under-19 rugby was 0.102 TPL per metre. When comparing the positions of under-19 rugby to the average mean, the positions lock (0.112), props (0.108) and lose forwards (0.105) all experienced higher TPL per metre. The fullback (0.092), wings (0.093) and flyhalf (0.095) all backline playing positions experienced lower TPL per metre than that of forwards. These values agree with the TPL in Table 4.1, this shows that the TPL and TPL per metre experienced by different playing position are higher in forwards than in backline players for u/19 level rugby. Scrumhalf and centre revealed the highest TPL per metre in under-19 rugby for backline players, this is due to the nature of position play where scrum half position requires high levels fitness and as high physical demands but lower maximum velocities compared to other backline positions.

5.3 Total distance covered

The total distance covered during match-play is measured in metres (m). Distance covered by athletes during competitions is one of the most studied variables in sports science (Belka *et al.,* 2014). The results for total distance covered by rugby players shows that significant differences exist between different playing positions in under-19 rugby players. When comparing the average mean 5733.5 m of rugby players for 11 matches in 2019, the fullback position covered the highest distance 6119.2 m, followed by the scrumhalf 5872.6 m, centres 5800.3 m and flyhalf 5689.4 m, all backline positions. The forwards covered lower distances than that of backline players, with exception for the hooker covering a mean distance of 5796.7 m. Lock 5695.8 m and loose forwards 5692.1 m had similar distances. The lowest mean value for TD was by the props, covering 5584.5 m on average. Thus, confirming that distances covered in under-19 rugby are higher in backline players compared to that of forwards. Forward positions are similar in distance, while the backline positions show higher distances as expected amongst backline players. The changing nature of the game shows that under-19 rugby players fitness and physical demands in running distances has improved.

For all other positions the minimum TD covered during a single match was between 4092.5 m by the fullback and 4764.8 m by the wing. From these values we can conclude that all positions

covered a minimum TD played above the 4000 m per game, except for props. Interestingly, the distances covered by fullback may vary greatly from match to match.

The maximum TD covered by a player in a single match was by the props covering 7811 m. The possible reason for this could be a replacement positions of props are relatively common for under-19 rugby players during match-play. Thus, replacements used on the position prop to improve TD covered in the prop position at under-19 rugby.

When comparing TD covered of the study of rugby under-19 players to that of TPL, it shows that forward position experienced a much higher TPL and covered lower distances than that of backline players. Backline players experienced lower TPL and higher distances for positions of wing and fullback, but scrumhalf and centres had similar TPL than forward players, although scrumhalf covered higher distances in a match. These findings make sense when looking at the inherent aspects of the game of rugby.

When comparing the results of the under-19 study to other studies in rugby, the under-19 study showed differences in the physical demands of distance covered. The under-19 study showed higher distances compared to the study of Deutsch *et al*. (1998) who analysed six players during four under-19 matches at different levels of play, the backs had a lower overall TPL they covered the greatest distance, with props and locks covering 4400 ± 398 m, back row 4080 ± 363 m, inside backs 5530 ± 337 m and outside backs 5750 ± 405 m. One can conclude that the physical demands of rugby players have improved and are physically more demanding than a decade ago. Cunningham *et al*. (2016) noted that u/19 rugby league players covered distances of 5 – 6 km during match-play, while Twist *et al*., (2014) noted u/19 rugby players covering distances 5 – 8km. These measures of distance are similar to those of the under-19 study.

Venter *et al.* (2011) showed that u/19 players covered on average a total distance of 4469.95 ± 292.25 m during a game. The front row forwards covered the greatest total distance (4672.00 ± 215 m), followed by outside backs (4597.93 ± 210.18m), inside backs (4307.78 ± 214m), and then back row forwards (4302.1 ± 529.82 m). Distances measured by Venter *et al*. (2011) are similar to that of Deutsch *et al.* (1998) and can be due to time played by u/19 rugby competitions are less than senior level as reported by Cuniffe *et al.* (2009). The under-19 study showed higher levels for all positions on average, one can conclude that the level of fitness has improved in the past decade and that the physical demands of under-19 rugby need to be assessed seasonally.

When the under-19 results, one can conclude that a minimum distance covered by all rugby players was more than 4000 m on average per match. The highest mean values for under-19 rugby show that players on average cover distances of 6119.2 m by full back and the lowest average mean of 5584.5 m by the props. The average mean of 5733.5 m for under-19 rugby players show that on average players should be able to cover a distance of 5733.5 m per match.

These distances covered are similar to more recent studies done in u/19 rugby but higher than a decade ago. Interestingly, is that props managed to cover above 5500m on average per game shows that forwards are fitter and more mobile than in previous studies. The following differences were noted (Read *et al*., 2017). They also noted that the total distances covered by under-18 and academy rugby players differed. The results of the showed that forwards from the academy (5461 ± 360 m) and school (4881 ± 388 m) were likely, and very likely to cover less total distance than academy (5639 ± 368 m) and school backs (5260 ± 441 m) (Read *et al*., 2017). Read *et al*. (2017), also noted that distances covered by school players are substantially less than previously reported for international U20 players (forwards: 5370 ± 830, ES = 0.98; backs: 6230 ± 800 m, ES = 1.94). Total distance covered in Pro 12 rugby players (forwards: 5639 ± 762, ES = 1.52; backs: 6172 ± 767 m, ES = 1.82) (Cunningham *et al*., 2016; Reardon *et* al., 2015). Academy backs also have less total distance than older age-grade players (Cunningham *et al*., 2016) and one study shows that senior players (Reardon *et al*., 2015), whereas the forwards are similar to data reported in these studies. Read *et al*. (2017) also noted that the differences represent comparable patterns from previous studies (Austin *et al*., 2011; Quarrie *et al*., 2013) that have suggested searches for open space by backs and the subsequent repositioning in the field explain these findings (Cahill *et al*., 2013; Read *et al*., 2017).

Backline positions were more active from match to match covering higher distances than those of forwards. This agrees with the differences in physical performance have been noted between forwards and backs. With regards to the positional demands for rugby, players are divided into tight forwards (props and locks), loose forwards (hookers, flanks and eighth men), and scrum half, inside backs (fly half, and centres) and outside backs (wings and fullbacks) (Tee *et al*., 2016).

The physical demands and intensities for forwards and backs differ greatly from one another. Forwards and backs playing position requirements are inherently different due to the physical

activity requirements of each position (Tee *et al*., 2016). Thus training and conditioning programmes should be designed differently for forwards than backs, with higher running distances for backs, although forwards should also have a high level of distance covered than in past seasons. This agrees that there have been major changes in the physical demands of rugby over the past three decades (Schoeman *et al*., 2017). This can also be linked to the improvement seen in distances covered in under-19 rugby.

Total distance covered in VB 1 - 5

A breakdown of the TD covered in VB 1 – 5 to be noted:

- Velocity band 1: Standing No locomotor activity (0 - 0.1 m.s-1),
- Velocity band 2: Walking: Either strolling locomotor activity in a forwards, backwards, or sideways direction (0.2 – 1.7 m.s-1),
- Velocity band 3: Jogging: Slow, non-purposeful running with no obvious acceleration (1.8 – 3.6 m.s-1),
- Velocity band 4: Running: A fast running action with distinct elongated strides, effort and purpose (3.7 – 5.3 m.s-1),
- Velocity band 5: Sprinting: Running with maximum effort or at maximum speed. (>5.4 m.s-1),

The mean for all playing positions VB1-5

The mean distance covered by under-19 rugby players in VB1 (standing to walking) was 2771 m, VB2 (walking to jogging) was 2182.9 m, VB3 (jogging to running) was 430.1 m, VB4 and 5 (running to maximum sprinting) was 217.6 m. This illustrates that the highest distances were covered in VB 1 and 2, with much lower distances covered in VB 3, the VB 4 and 5 had the lowest distances covered during a match.

VB 1 distances covered

The mean distances in VB 1 was highest in positions fullback 3318.7 m and wings 3012.1 m. The lowest distance was covered by the scrumhalf covering only 2303.7 m. Similarities can be seen by all forward positions, lock, loose forwards and props. It is also notable that the fullback had the highest variation in distance covered over 11 matches. The distances for VB1 confirm that fullback covered the most distance in a game. The scrumhalf the lowest distance. Props had the highest distance amongst forward positions, although props, loose forwards and locks all covered similar distances in VB1. All positions covered high distances above 2515.1 m.

VB 2 distances covered

The mean distances in VB 2 was highest in positions hooker 2757 m and the scrumhalf 2617 m. The lowest distance was covered by the wings covering 1697 m and the fullback 1958.7 m. Similarities can be found between forward positions, lock, loose forwards and props as well as backline positions flyhalf and centres. The forwards all had similar values above 2189.4 m for prop to 2369.4 m for the locks in VB2.

VB 3 distances covered

The mean distances in VB 3 was highest by backline positions scrumhalf 645.5 m and the flyhalf 611.1 m. The lowest distance was covered by the props covering 256.3 m and the hooker 348.9 m.

Similarities can be found between forward positions, hooker and lock as well as backline position wings. Centres covered 506.8 m, flyhalf and the scrumhalf covered the most distance in VB3, all players belonging to the backline. It is notable that the flyhalf had the greatest variation in distance covered between rugby matches.

The distances for VB3 confirm that the scrumhalf, flyhalf and centres had comparable distances, with scrumhalf achieving the highest metreage 631.4 m. Loose forwards covered the highest metreage of 442.4m amongst the forwards. Lock and hookers covered similar distances, while the props had the lowest metreage of 247.7 m in VB3.

VB 4 and 5 distances covered

The mean distances in VB 4 was highest by backline positions centres 358.5 m and the wings 277.7 m. The lowest distance was covered by the props covering 82.2 m, the locks and the loose forwards also covered low distances. Similarities can be found between forward positions having lower distances for props, hooker and lock when compared to backline positions centres, wings, fullback and flyhalf. The distances for VB5 confirm that the backline players wings metreage of 280.7 m had the highest distances compared to all other positions. Centres covered the second most metreage of 232.9 m. Loose forwards covered 67.9 m and had the highest metreage of all forwards in VB5.

The maximum distance in VB 4&5 covered by a player in a single match was by the centre 560.3 m, followed by the wings 501.9 m and the fullback 425.5 m. The minimum distance covered by a player in VB 4 and 5 was by the props 8.4 m, followed by the locks 36 m. This

can indicate that there can be a great variation between matches for different playing positions in VB4 and that backline players had a much higher distance covered compared to forwards.

When comparing data of under-19 rugby players in a 75 minutes game to that of other studies (Cunniffe *et al*., 2009; Deutsch *et al*., 1998; Venter *et al*., 2011), the under-19 rugby players covered much higher distances for all positions. The distance covered showed that 2800m was spent standing and walking, 1900m jogging, 700m cruising, 990m striding, 320m high intensity running, and 420m sprinting (Cunnife *et al*., 2009). It should, however, be noted that Cunniffe *et al.* (2009) analysed 83 minutes from the game, while Deutsch *et al.* (1998) analysed 60 minutes each from five games. Venter *et al.* (2011) showed that under 19 players covered on average a total distance of 4469.95 ± 292.25 m during a game. The front row forwards covered the greatest total distance (4672.00 ± 215 m), followed by outside backs (4597.93 ± 210.18m), inside backs (4307.78 ± 214m), and then back row forwards (4302.1 ± 529.82 m). Distances measured by Venter *et al*. (2011) are similar to that of Deutsch *et al.* (1998) and can be due to time played by under 19 rugby competitions are less than senior level as reported by Cuniffe *et al.* (2009). These results of under-19 rugby players differ from these studies and show that higher distances were covered in a shorter time period. This can be due to the changing nature of rugby and higher physical demands in under-19 rugby than in previous years.

5.4 Total distance percentages

According to Table 4.21 the mean values for all VB 1-5 total distance percentages (td%) can be noted. The mean values show that the VB1 (48.5%) and 2 (38.1%) had the highest td% compared to the time spent in VB3 (7.5%), VB4 (3.8%) and VB5 (2.1%). All players had high td% for VB1&2. The number (N) of players tested by GPS technology was 151.

VB1 and VB2 Td%

All playing position had high td% in both VB1 and VB2. The positions with the highest td% in VB1 was the fullback with 54.4% and the wings 53.2% and props 53.1%. Similarities between the forward positions lock and loose forwards ranged between 48-53%. The centre and flyhalf and hooker had similar td%. The lowest td% were by the scrumhalf 38.9%.

In VB2 td% the hooker 47% had the highest td%, the lowest by the wing 30.2%. Similarities can be seen by fullbacks 31.9% and wings 30.2% as the two lowest percentages in VB2. The loose forwards, locks, props and scrumhalf all had td% above 40%. This hooker had the

highest td% in VB2. All players showed a high td% in VB2. Thus, all players covered high distances walking to jogging in VB2.

VB3 Td%

In VB3 the highest mean values were achieved by the scrumhalf 11.1% and the flyhalf 10.7%. The lowest mean value was by the props 4.7%. Similarities according to the means can be seen by the scrumhalf and flyhalf that had the highest td% of all players. The wing and fullback shared similar td% in backline players. The forward positions hooker and lock had similar td% values. The props had the lowest td% of all positions in VB3. Therefore, props td% when jogging was the smallest of all positions, while the scrumhalf and flyhalf had the highest jogging td%.

VB4 and VB5 Td%

The highest mean values of td% in VB4 was by the centres 6.2% and the wing 4.9%, while in VB5 wings had higher td% of 5% and centres a lower td% of 4.1%. The lowest mean value in VB4 was by the props 1.4% while in VB5 props 0.4%, forwards all had very low td%, loose forwards had the highest td% of all forwards.

5.5. Duration in velocity bands

5.5.1 Total duration

The total duration (Td) measured the time spent in each VB 1-5, measured in seconds (s). The mean total duration in VB1 was 60.3 min, VB2 was 12.3 min, VB3 was 1.4 min, VB4 was 0.6 min, and VB5 was 0.3 min.

Td VB1

VB1 had the highest duration of all velocity bands. When comparing the total duration in VB1 by different playing positions, the highest mean was by the wings 62.5 min, followed by the fullback and centres. The lowest mean value was by the scrumhalf 58.4 min. All positions had a mean Td above 58.4 min of a 75min match.

Td VB 2

In VB2 the hooker 15 min and the scrumhalf 14.2 min had the highest mean Td. The lowest mean value was by the wing 9.6 min. Similarities can be seen by centres, flyhalf and fullback for Td in VB2. The forward positions of loose forwards, locks, props all had similar Td. All players showed a high Td in VB2 when compared to VB 3-5. Thus, all players covered high durations walking to jogging in VB2.

Td VB3-5

The Td mean value for all the players in VB3 was 1.4 min, VB4 was 0.6 min and VB5 was 0.3 min. The combined total for VB3-5 was 2.3 min. VB3 to 5 in comparison with VB 1 and 2 was significantly small for a 75 minutes match. Backline players had the highest durations in VB3-5 compared to forwards. Centres totaling 3.2 min and scrumhalf 2.9 min. Forwards did not have any relevant time in VB 4 and 5.

The highest mean values of Td in VB3 was by the scrumhalf and flyhalf. The wings, fullbacks and centres had similar values. Props had the smallest values of 0.9 min. The lock and hooker position had similar Td. The Td for VB4 made up only 1 min of the playing time. The highest mean values for Td in VB4 was by centres 1 min, followed by the wings and all backline players. Loose forwards had the only relevant Td for forwards in VB4. The mean for all players in VB4 was 0.6 min, which is significantly small to the Td of a match of 75 min. High intensities of running are characteristics of VB4. The Td for VB5 showed that wings 0.6 min had the highest mean values, followed by centres 0.5 min. Props had a 0 min value, meaning they did not spend time in VB5. Other forward positions had a mean of 0.1 min, which suggests duration are very low in VB5 for forwards or nonexistent.

High-intensity bursts comprise of running, sprinting, tackling, mauling, and continuous change of direction under high velocities. Physical activities also include longer low-intensities activities that consist of jogging and walking during the game (Duthie *et al.,* 2003). The demands on a rugby player are physically taxing and demand a high level of fitness due to the competitiveness and the inherent physical match load of the game (Shaun *et al*., 2015). McLean (1992) determined that when the ball was in open play, the average running pace of players central to the action ranged from 5 to 8m/s.

Venter *et al.* (2011) reported maximum speeds reached did not differ significantly between the groups of players. Outside backs reached speeds of 33.10 ± 0.79 km.h" 1, followed by inside backs (27.97 ± 1.42 km.h- 1), back row forwards (26.01 ± 2.32 km.h"i), and then the front row forwards (23.01 ± 2.03 km.h"i). The highest average player running speeds over the games were 4.69 ± 0.38 km.h"i (outside backs) and the lowest were 4.30 ± 0.47 km. h"i (back row forwards). According to Austin *et al*. (2011) the durations of the most intense repeated high intensity exercise bouts for each position ranged from 53s to 165s and the minimum recovery periods between repeated high intensity exercise bouts ranged from 25s for the back row forwards to 64s for the front row forwards.

The most intense periods of activity are likely to last as long as 120s and as little as 25s recovery time may separate consecutive repeated high intensity exercise bouts. Venter *et al*. (2011) reported that the time spent walking in under 19 match play for the outside backs are on average 36 min 12 s ± 2 min 21s (60.34 ± 3.92%), which is significantly more ($p<0.05$) than the 25 min 15 s ± 5 min 59s (42.1 ± 9.99%) of the front row forwards. Venter *et al*. (2011) also showed that props and locks spent on average more time jogging (15 min 40 s ± 2 min 16 s or 26.11 ± 3.77%), compared to outside backs (9 min 22 s ± 1 min 23 s or 15.6 ± 2.3%). Outside backs spent more time sprinting (39.96 ± 4.48 s or 1.11 ± 1.18%) than inside backs (25.92 ± 10.8 s or 0.72 ± 0.30%), the front row forwards (17.28 ± 8.28 s or 0.48 ± 0.23%), and back row forwards (17.28 ± 4.68s or 0.48 ± 0.13%) (Venter *et al.,* 2011). Within elite under-19 colts' rugby, forwards spent a larger percentage of time standing still (46%) compared with the backs (39%) and covered a shorter distance in all gait movements except jogging (Deutsch *et al*., 1998). Although the Vb3-5 were shorter duration than that of VB1-2, the of distance covered by players were more explosive, meaning that maximum velocity achieved in shorter durations during the game.

5.6. Maximum velocity

The data in Table 4.37 provides information on the mean maximum velocity (MV) achieved by the different player positions in under-19 rugby measured as metre per second ($m.s^{-1}$). The average mean MV value for all positions achieved was 8.3 $m.s^{-1}$. The highest mean MV was achieved by the position wing 9.45 $m.s^{-1}$ and 9.07 m for centres. The minimum MV achieved was by the props at 7.06 $m.s^{-1}$. The fullback (8.86 $m.s^{-1}$), flyhalf (8.72 $m.s^{-1}$) and scrumhalf (8.25 $m.s^{-1}$) achieved above 8 $m.s^{-1}$. It is notable that the top MV achieved were by backline players. The highest MV achieved by a forward was by loose forwards at 7.97 $m.s^{-1}$ followed by hooker (7.75 $m.s^{-1}$) and lock (7.7 $m.s^{-1}$) and props. Players have become more explosive and reach higher maximum velocities than in the past. Backline players are fast positions on the field and show higher speeds than all forwards. wings are the fastest players on the field, followed by centres. Forwards have similar speeds for maximum velocity and are the centre of play, they dominate the game are constantly involved in the physical aspect of the game, require higher physical demands. They are involved in ball carrying, tackling as well in rucking and mauling, these aspects of the game are on average higher in TPL but lower in maximum velocities, while backline positions are involved in faster and more explosive maximum velocities in running and maximum sprinting although having lower TPL. The differences in forwards and backs are clearly show that the physical demands differ between positions in the game of rugby at under-19 rugby.

5.7 Summary

The results for TMA through use of GPS system of the Catapult Minimax X4 revealed that the physical demands placed on under-19 rugby show difference in positional play. Forwards and backs physical demands are different and should be taken into account when setting up coaching as well as strength and conditioning programmes for under-19 rugby players.

Data analysis of the physical demands of under-19 rugby included the following categories: total player load and total player load per metre, total distance covered in a match as well as in the velocity bands 1 – 5, total distance percentage and maximum velocities for all playing positions. The study was done in the 2019 rugby season and provided information that will be beneficial to both rugby player, conditioning coaches and rugby coaches involved in rugby at under-19 level.

CHAPTER 6
Conclusion and Future Research

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

6.1 Introduction

The aim of the study was to investigate physical demands of under-19 rugby through use of tri-axial accelerometer GPS technology and to create a physical activity profile of under-19 rugby. This was done through analysis of the physical activity of the under-19 first rugby team of Grey College of 2019. GPS technology, Catapult Minimax X4 was used to research the various physical aspects of the under-19 rugby players that participated in the study during the 2019 rugby season. The under-19 first rugby team of the school played 17 inter-schools matches, of which 11 were successfully monitored. The primary analysis objective was to provide data on the movement patterns to obtain information on physical demands and positional differences in u/19 rugby. The physical demands measured were total player load, total player load per metre, distance covered, total distance percentage in velocity bands 1-5, total duration in velocity bands 1-5, and the maximum velocity. The positional groups od forwards and backs were compared to assess the differences between the difference in playing positions with respect to the data from the movement patterns of u/19 rugby players. The use of portable GPS devices has become a popular and convenient method to quantify movement patterns and physical and running demands of rugby using GPS technology (Akenhead *et al*., 2014). Establishing player specific physical demands may give insight to both coaches, conditioning specialists and players at under-19 level. The gap of research data on junior rugby needs to be addressed (Read *et al*., 2017).

The purpose of research is understanding “why” the research is being done? What the goals and purposes are? We can ask the same question as to why research must be done in under-19 rugby? What goals do we hope to achieve? These questions in need to be answered in future research. For the purpose of this study we asked: “What are the physical demands in under-19 rugby?” The answer we can find are not only in the results, but in the development of players in the future of under-19 rugby. The results don’t lie, they give indications to what the true demands of under-19 rugby players had to go through to achieve an unbeaten season in first team schoolboy rugby. I personally believe that it is some of the most exciting and entertaining rugby one can watch. To be part of such experience leaves many questions. As to will conditioning specialists take note of these findings. Will they design conditioning programs and coaching sessions in a new light? Taking into consideration the defined physical demands of under-19 rugby.

Rugby as any sport, is continually developing and changing, for this reason researchers will need to continue asking questions about what players and coaches are doing in preparation for the new seasons that lie ahead. Continue to do the same and you die, evolve and become

better by doing things differently helps us learn how to become champions. I guess that is one of the reasons the Springbuck team are World Cup rugby winners, as they never gave up pushing the limits of physical demands of rugby.

6.2 Conclusion

The results of the study revealed that in 11 rugby matches that were played in 2019 the following physical demands were assessed for the physical profile of under-19 rugby players:

Total player load (TPL) and TPL per metre showed that forwards experienced higher intensities and work rate than that of backline players, with an average mean of 583.7 (au) for all positions and locks attain the highest TPL of 636.4 (au).

Total distance covered showed that backs achieved higher distances than forwards, fullbacks achieving highest distances of 6119.2 m, props covered lowest distances of 5584.5 m and that the average mean for all players was 5733.5m.

Total distance percentages showed that the higher distance percentages were found in VB1 and 2, while shorter distance percentages were seen in VB3-5. Wings were the fastest followed by centres, and VB 3 showed that forwards were most active.

Total duration showed that most time spent in a match was standing to walking. VB1 had an average mean of 60.3 minutes, VB2 12.3 minutes and VB3 1.4 minutes, VB4 0.6minutes and VB5 0.3 minutes. One can make the conclusion that lower distance in VB3-5 was meant that higher velocities in these distances were achieved, and that lower velocities are associated with VB1 and VB2.

Maximum velocity showed that z mean average of 8.3 $m.s^{-1}$ for all players. Backline players achieved highest velocities with wing 9.45 $m.s^{-1}$ and 9.07 m for centres and fullback achieving 8.72 $m.s^{-1}$ and that forwards forward was by loose forwards at 7.97 $m.s^{-1}$ followed by hooker (7.75 $m.s^{-1}$), lock (7.7 $m.s^{-1}$) and the props at 7.06 $m.s^{-1}$.

The rapid changes and improvements of the physical performance of rugby players in the past decades (Schoeman *et al*., 2017), the changing nature of the game needs to be assessed from junior to senior level. TMA through the use of GPS technology has become a common tool in quantifying the physical demands of rugby players across the globe. This knowledge

and understanding the demands placed on rugby players at school level should be beneficial to all involved in the rugby world.

6.3 Limitations and Future research

Further research could include that more studies be done in South Africa under-19 level. Rugby players need to be assessed seasonally to determine fitness levels and physical demands needed to achieve the desired goals of rugby coaches as well as strength and conditioning specialists need consider relevant up to date data of rugby teams when setting up programmes for under-19 rugby players. This can be done though TMA using GPS technology as a measuring tool. Another consideration would be to set up strength and conditioning programmes and coaching programmes that are positionally specific for forwards and backline players.

Further research could be done in the development of rugby to measure different age groups as low as under-14, as the game has become even more competitive and demanding more of players from a young age. Future studies should be combined video-based performance analysis in GPS data to establish more specific profiles of schoolboy rugby players. The study only made use of 15-man active on-field player positions during match-play. One can look at defining the demands of all player and replacements separately, also not only looking at the quantification of match-play but also at what the training load of players are compared to that of match-play.

Limitations to the study could be:

- Only 11 matches were analysed in the season, one could have assessed more matches and would have had more data to assess.
- Only one under-19 rugby team was tested during the study, which had specific game plan and tactics.
- A number of reserves were used to replace players, it would be more accurate if all players were able to complete the match and that reserves be monitored separately.
- The speed zones set for VB 1-5 were predetermined for all players. VB could rather be set out per player according to their maximum velocity recorded.

- Player load was calculated using the Catapult GPS system software, without taking static exertion into account which cannot be measured by GPS.

- A number of other physical demands could have been measured such as work to rest ratios, accelerations and decelerations impacts and HR and changes in direction.
- Specific research on all position 1-15 and separate calculations for reserves.

The use of GPS technology as a tool to better monitoring and manage rugby players is an essential element of the game, not only in developing players physical abilities, but also keeping players free of injury and prevent overuse in conditioning and training sessions.

Under-19 level is a gateway that provides players to develop into professional players of the future if well managed. Many more limitations can be looked at, but for now, at least, TMA of under-19 rugby union players during match-play has been assessed through the use of GPS technology at school level in South Africa.

CHAPTER 7
Reflection on the Research Process

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

7.1 Introduction

The research process I have taken is a journey over a thousand hills, some more challenging than other, some needed to be climb over and others around. The journey of acquiring and seeking new knowledge in order to provide insights to under-19 rugby. It started as a question that needed to be answered: What are the true demands of under-19 rugby players at school level. How can we conditioning schoolboy players properly, without knowing what physical demands are placed on under-19 rugby players and prevent overuse of training and reduce injury free and be adequately prepared physically fit for the game of rugby at under-19 level? After being involved in conditioning and coaching at school level for the past 10 years, watching the game develop and seeing the boys develop from boys to men that defend the honour of their school in the first team of Grey College. I realised I needed to answer the question in some way. Not playing for money but for glory are what schoolboys play for. Once realising that it is an important question that affects the lives of many young rugby players and coaches involved in schoolboy rugby around the world. I would try to take on the task of completing the research process. I realised that the journey is endless and that one needs to start somewhere. I struggled to get going, but as the words of Sir. George Grey has it: “When the occasion demands it, a Grey boy always comes up to scratch”. This true for the rugby team of 2019, who were ranked number 1 in SA at the end of the 2019 rugby season being unbeaten. It was a privilege to be able to monitor the players, even though they did not enjoy wearing the GPS units, they were willing. They placed the team first.

7.2 Reflecting on the research process

The research process cab be defined in 5 steps: Actually 6!

Number 1: Find the right topic: You need to be interested in the project otherwise there will be no progress. Passion and perseverance go hand-in-hand.

Number 2: There must be a greater purpose for doing the research. Something that motivates you beyond your own interests, is making a difference in lives of others. truly that is what coaches and conditioners do.

Number 3: Find the right study leader, without his help and patience and motivation it would be far more difficult.

Number 4: Be prepared to put in the effort. Follow the research process, but also find your own way to manage writing. I once heard a quote by one of the boys at school that said, “Apply bum to chair”, which reminded me of my earlier years of study. Nothing can be done until you decide to sit down and start working.

Step 5: Don’t give up! Yes, there are times when it seems impossible and you feel overwhelmed. My advice would be as Winston Churchill said in World War 2: “Never, never, never, never ever give up!” These words if taken to heart will help you win the war, at least the one inside of you.

Step 6: “Acknowledge God in all your ways and he will make your paths straight.” Proverbs 3:5-6 (The Bible).

If this does not work for you, you can always Google the research process.

7.3 Personal remarks

What a privilege to have been able to complete the research process. I would have liked to do much more, but the process is endless. I would like to acknowledge the First Rugby team of Grey College of 2019; these boys are true champions! I would also like thank my study leader for his inputs and guidance. Lastly, I would like to thank my wife for her support and love while I had to sit and complete the Masters’ degree. All glory to Jesus, the author and finisher of my faith!

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APPENDICES

A.1. INFORMATION DOCUMENT

Appendix A.1.
Information document

RESEARCH PROJECT (Magister Artium):
Research title: Time motion analysis of Under – 19 Rugby Union players during match-play

Dear Participant

I, TC Steyn, am doing research on the physical demands of Under-19 rugby using GPS technology. In this study we want to learn more about what actually happens in a rugby match using GPS as a measuring tool.

I am inviting you to participate in this research study, which will be done on the Grey College First rugby team during the 2019 rugby season.

What is involved in the study: Data will be collected from all inter-schools matches played by the Grey College First rugby team during the 2019 rugby season. Every player's age, mass, stature and anthropometric data will be collected one week prior to the start of the season to give an indication of the physical differences between players and their positions. Every player will wear the GPS unit in a padded protected harness, positioned on their back between the shoulder blades area underneath his rugby jersey. After the match, data will be downloaded to a personal computer and further analysis will be carried out using the system software provided by the manufacturer. The following will be measured: the total distance covered, high intensity distance covered, work to rest ratios, changes in direction and velocity, impacts and the implications for fitness training.
Participation is voluntary: Participant may refuse to be involved without being penalized; the subject may discontinue participation at any time without being penalized.

Possible Risks: Participation in rugby union 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 programs for better and more consistent performance for teams and individual players.

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

Contact details of researcher:

Christopher Steyn
Tel: 083 494 5003
Email: csteyn@gc.co.za

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
Thank you for participating in this research project.

Regards,

_____

Christopher Steyn
Principal researcher

A.2. INFORMED CONSENT FORM

Appendix A.2.
Informed Consent Form

RESEARCH PROJECT (Magister Artium):

Research title: Time motion analysis of Under – 19 Rugby Union players during match-play

You/your son 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/his inclusion in the Grey College First rugby team. This research will investigate the physical demands placed on rugby players during the 2019 season. It is hoped that the findings of this study will assist your coaches and conditioning staff to improve training and fitness programs for better and more consistent performance.

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

Contact details of researchers:

Christopher Steyn
Tel: 060 5875 991
Email: csteyn@gc.co.za

Dr. Riaan Schoeman
Tel: 051 401 3207
Email: SchoemanR@ufs.ac.za

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

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

_____ _____

Signature of Participant Date

_____ _____

Signature of Witness Date

A.3. MINOR ASSENT FORM

Appendix A.3.

Minor Assent Form

RESEARCH PROJECT (Magister Artium):

Research title: Time motion analysis of Under – 19 Rugby Union players during match-play

MINOR ASSENT FORM

You are being asked to take part in a research study being done by the University of the Free State. In this study, we are interested to know more about your movement patterns and performance during Grey College first rugby team matches played at under-19 level during the 2019 rugby season. We have asked your parent or legal guardian whether it is OK for you to participate, but now we want to see if it is OK with you. If you decide to take part in this study, you will be given a GPS monitor to wear while playing matches for the Grey College first rugby team at under-19 level. The monitor will not hinder you in anyway while playing and will add no additional weight.

All the information we collect will be kept confidential and you don't have to share any of your information with anybody else. We will not use your name so everything will remain private. By signing this you are showing that you understand what is going to be happening and have asked any questions you may have about the research. You can also ask questions later if you cannot think of them now. Signing this form does not mean that you have to finish the study- you can pull out from the study at any time without explaining why.

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

Sincerely

Christopher Steyn

083 494 5003

csteyn@gc.co.za

Permission

I, _____, An under-19 rugby player, hereby give permission to TC Steyn to collect GPS data from my rugby matches played during the 2019 season for the First rugby team of Grey College.

_____ _____

Name of participant Parents signature

_____ _____

Minor's signature Date

B.1. PERMISSION LETTER

Appendix B.1.
Permission letter – Head coach and Director of rugby of Grey College First Rugby Team

Dear Mr. Wessel du Plessis and Mr. Bobby Joubert
Head coach and Director of Rugby of the Grey College First rugby team

RESEARCH PROJECT (Magister Artium):
Research title: **Time motion analysis of Under – 19 Rugby Union players during match-play**

TC Steyn (Masters Student) and the Department of Exercise and Sport Sciences of the University of the Free State, hereby request permission to conduct research on the Grey College First rugby team players participating at under-19 age level during the 2019 inter-schools rugby season. The research will be done with the aid of Prof. Derik Coetzee (Adjunct Professor and Head of Department: Department Exercise and Sport Sciences) and Dr. Riaan Schoeman (Junior Lecturer: Department Exercise and Sports Sciences).

I am doing research on the physical demands of under-19 rugby players focusing on the time motion analysis using GPS technology to determine and learn more about what actually happens in a rugby match, using GPS technology as a tool for measuring the physical performance of under 19 rugby players participating at First team rugby level.

The researcher will make an appointment with the team to explain the informed consent form and research procedure of the study. This part of data collection will commence at the participating school. Data will be collected from all inter-schools matches played by the Grey College First rugby team during the 2019 season. Every player will wear the GPS unit in a padded protected harness, positioned between his left and right scapula, in the upper thoracic spine area underneath his rugby jersey. After the match, data will be downloaded to a personal computer and further analysis

will be carried out using the system software provided by the manufacturer. The following variables will be investigated: the total player load, total player load per metre, total distance covered, total distance percentages, total duration maximum velocity.

The data collected will be invaluable for future use by all involved and serve as a sport specific tool for conditioning and training programs. Participation is voluntary, and refusal to participate will involve no penalty or loss of benefits to which the subject is otherwise entitled; the subject may discontinue participation at any time without penalty or loss of benefits to which the subject is otherwise entitled.

Players will be equipped with a Catapult Minimax X4 tri-axial accelerometer prior to the warm-up of the rugby match by the researcher. Participants will not be placed at risk by wearing the device and it will not have any effect on the players' performance on the field.

The researcher will aim to analyse all inter-school matches of the Grey College First rugby team in the 2019 rugby season.

The goal of this study is:

- To determine the physical demands of elite under-19 rugby players participating in the First rugby team of Grey College during the 2019 rugby season.
- To implement time motion analysis to assess the physical performance of elite under-19 rugby players and the movement patterns in order to determine the frequency and duration of each component involved.

To summarize, in order to complete the research, permission is hereby requested to obtain body composition measurements as well as tri-axial accelerometer data from the participating elite under-19 rugby players participating in the First rugby team of Grey College in the 2019 inter-schools rugby season on the:

- the total player load

- total player load per metre
- total distance covered
- total distance percentages
- total duration maximum velocity

Participation would be absolutely free of any costs and no payments or remuneration will be made to participants. After completion of the study the results will be published. With this letter, I would like to request permission from you to do my research on the players of the Grey College First rugby team during the Grey College First rugby team 2019 inter-schools season.

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

Sincerely
Christopher Steyn
083 494 5003
csteyn@gc.co.za

Permission

I, _____, Head coach of the Grey College First rugby team, hereby give permission to TC Steyn to collect GPS data from Grey College First rugby team players during the 2018 season.

_____ _____

W Du Plessis Date

I, _____, Rugby director of the Grey College First rugby team, hereby give permission to TC Steyn to collect GPS data from Grey College First rugby team players during the 2019 season.

_____ _____

B Joubert Date

B.2. PERMISSION LETTER

Appendix B.2.
Letter requesting permission – Free State Department of Education

Dear
FREE STATE DEPARTMENT OF EDUCATION

RESEARCH PROJECT (Magister Artium):

Research title: **Time motion analysis of Under – 19 Rugby Union players during match-play**

TC Steyn (Masters Student) and the Department of Exercise and Sport Sciences of the University of the Free State, hereby request permission to conduct research on the Grey College First rugby team players participating at under-19 age level during the 2019 inter-schools rugby season. The research will be done with the aid Prof. Derik Coetzee (Adjunct Professor and Head of Department: Department Exercise and Sport Sciences) and Dr. Riaan Schoeman (Junior Lecturer: Department Exercise and Sports Sciences).

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I am doing research on the physical demands of under-19 rugby players focusing on the time motion analysis using GPS technology to determine and learn more about what actually happens in a rugby match, using GPS technology as a tool for measuring the physical performance of under 19 rugby players participating at First team rugby level.

The researcher will make an appointment with the team to explain the informed consent form and research procedure of the study. This part of data collection will commence at the participating school. Data will be collected from all inter-schools matches played by the Grey College First rugby team during the 2019 season. the total player load, total player load per metre, total distance covered, total distance percentages, total duration maximum velocity.

Every player will wear the GPS unit in a padded protected harness, positioned between his left and right scapula, in the upper thoracic spine area underneath his rugby jersey. After the match, data will be downloaded to a personal computer and further analysis will be carried out using the system software provided by the manufacturer. The following variables will be investigated: the total distance covered, high intensity distance covered, work to rest ratios, changes in direction and velocity, impacts and the implications for fitness training.

The data collected will be invaluable for future use by all involved and serve as a sport specific tool for conditioning and training programs. Participation is voluntary, and refusal to participate will involve no penalty or loss of benefits to which the subject is otherwise entitled; the subject may discontinue participation at any time without penalty or loss of benefits to which the subject is otherwise entitled.

Players will be equipped with a Catapult Minimax X4 tri-axial accelerometer prior to the warm-up of the rugby match by the researcher.

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

The researcher will aim to analyse all inter-school matches of the Grey College First rugby team in the 2019 rugby season.

The goal of this study is:

- To determine the physical demands of elite under-19 rugby players participating in the First rugby team of Grey College during the 2019 rugby season.

- To implement time motion analysis to assess the physical performance of elite under-19 rugby players and the movement patterns in order to determine the frequency and duration of each component involved.

To summarize, in order to complete the research, permission is hereby requested to obtain body composition measurements as well as tri-axial accelerometer data from the participating elite under-19 rugby players participating in the First rugby team of Grey College in the 2019 inter-schools rugby season on the:

- the total player load
- total player load per metre
- total distance covered
- total distance percentages
- total duration maximum velocity

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

With this letter, I would like to request permission from you to do my research on the players of the Grey College First rugby team during the Grey College First rugby team 2019 inter-schools season.

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

Sincerely
Christopher Steyn
083 494 5003
csteyn@gc.co.za

B.3. PERMISSION LETTER

Appendix B.3.
Permission letter – School Headmaster: Grey College

Dear
HEADMASTER OF GREY COLLEGE: Mr. Deon Scheepers

RESEARCH PROJECT (Magister Artium):

Research title: **Time motion analysis of Under – 19 Rugby Union players during match-play**

TC Steyn (Masters Student) and the Department of Exercise and Sport Sciences of the University of the Free State, hereby request permission to conduct research on the Grey College First rugby team players participating at under-19 age level during the 2019 inter-schools rugby season. The research will be done with the aid of Prof. Derik Coetzee (Adjunct Professor and Head of Department: Department Exercise and Sport Sciences) and Dr. Riaan Schoeman (Junior Lecturer: Department Exercise and Sports Sciences).

I am doing research on the physical demands of under-19 rugby players focusing on the time motion analysis using GPS technology to determine and learn more about what actually happens in a rugby match, using GPS technology as a tool for measuring the physical performance of under 19 rugby players participating at First team rugby level.

The researcher will make an appointment with the team to explain the informed consent form and research procedure of the study. This part of data collection will commence at the participating school.

Data will be collected from all inter-schools matches played by the Grey College First rugby team during the 2019 season. The total player load, total player load per metre, total distance covered, total distance percentages, total duration maximum velocity.

Every player will wear the GPS unit in a padded protected harness, positioned between his left and right scapula, in the upper thoracic spine area underneath his rugby jersey. After the match, data will be downloaded to a personal computer and further analysis will be carried out using the system software provided by the manufacturer. The following variables will be investigated: the total distance covered, high intensity distance covered, work to rest ratios, changes in direction and velocity, impacts and the implications for fitness training.

The data collected will be invaluable for future use by all involved and serve as a sport specific tool for conditioning and training programs. Participation is voluntary, and refusal to participate will involve no penalty or loss of benefits to which the subject is otherwise entitled; the subject may discontinue participation at any time without penalty or loss of benefits to which the subject is otherwise entitled.

Players will be equipped with a Catapult Minimax X4 tri-axial accelerometer prior to the warm-up of the rugby match by the researcher.

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

The researcher will aim to analyse all inter-school matches of the Grey College First rugby team in the 2019 rugby season.

The goal of this study is:

- To determine the physical demands of elite under-19 rugby players participating in the First rugby team of Grey College during the 2019 rugby season.

- To implement time motion analysis to assess the physical performance of elite under-19 rugby players and the movement patterns in order to determine the frequency and duration of each component involved.

To summarize, in order to complete the research, permission is hereby requested to obtain body composition measurements as well as tri-axial accelerometer data from the participating elite under-19 rugby players participating in the First rugby team of Grey College in the 2019 inter-schools rugby season on the :

- the total player load
- total player load per metre
- total distance covered
- total distance percentages
- total duration maximum velocity

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

With this letter, I would like to request permission from you to do my research on the players of the Grey College First rugby team during the Grey College First rugby team 2019 inter-schools season. Your assistance in this matter will be greatly appreciated. Please contact me with any questions or suggestions.

Sincerely
Christopher Steyn
083 494 5003
csteyn@gc.co.za

Permission

I, _____, Headmaster of the Grey College Secondary School, hereby give permission to TC Steyn to collect GPS data from Grey College First rugby team players during the 2019 season.

_____ _____

Mr. Deon Scheepers Date

APPENDIX C: Ethics approval letter

APPENDIX D: Turn it in report

APPENDIX E: Evaluation committee report