In-match running demands of South African university rugby union players using Global Positioning Systems

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SUMMARY

Rugby at university level is a fast paced, high collision game. The implementation of the Varsity Cup tournament among South African universities has sparked interest in university rugby cultures around the country. Match play running demands of university rugby players have not yet been explored in research. Changes in rugby laws and the evolving tactics of coaches in the game, requires new methods to achieve performance outcomes. Currently, there is limited published research on South African university rugby players and the use of total distance, high speed meters, maximum velocity, match intensity, number of accelerations and decelerations and velocity zones to analyse the demands during match play. The current study aimed at highlighting the in-match physical running demands of South African university rugby players using global positioning systems (GPS).

The first aim of the study was to investigate the in-match running demands of South African university rugby players by using GPS during match play for primary and secondary positional groups. The second aim was to determine differences in in-match running demands of primary and secondary positional groups between the 1st and 2nd halves of matches during the 2018 Varsity Cup rugby competition. This thesis followed an article format. Article one addressed the first aim and article two the second.

South African university rugby players (N=40) from two universities were assessed during match play over a competitive season by using GPS. Players were grouped into two primary positional groups, forwards (n=22) and backs (n=18), and five secondary positional groups, tight forwards (n=14), loose forwards (n=8), half backs (n=5), inside backs (n=6) and outside backs (n=7). The GPS analysis provided the following match-play movements: total distance; high-speed meters; maximum velocity; match intensity; number of accelerations and decelerations; and velocity zone. Three different match periods were used to describe the data.

Results of the first aim indicated differences between the primary positional groups and the secondary positional groups. Backs recorded higher results for running demand metrics, when compared to the forwards. Half backs recorded the highest total distance (6620.9±784.4m) ($p \leq 0.05$), and match intensity (77.7±11.6m/min) ($p \leq 0.05$). Outside backs

recorded the highest maximum velocity (8.385±1.242 $m.s^{-1}$) ($p \leq 0.05$). Loose forwards registered the highest number of accelerations (385.5±122.1), and decelerations (378.7±108.1). Backs recorded more meters within all three velocity zones measured and were significantly better than the forwards ($p \leq 0.05$). Half backs recorded the most meters in velocity zone three and outside backs recorded the most meters in velocity zone four and five ($p \leq 0.05$). Groups did not differ greatly regarding the number of accelerations and decelerations registered during the full match.

Results of the second aim followed similar trends to the first aim. The primary backs recorded higher results for all the measured metrics for both the 1^{st} and 2^{nd} halves. Backs recorded a greater total distance (3313.8±602.5m & 2947.8±887.7m), high speed meters (237.6±53m & 221.6 ± 64.6m) ($p \leq 0.05$), number of accelerations (382.80±105.5 & 353.03±123.2) and decelerations (378.6±85.4 & 344.9±107.4), total distance in all three velocity zones ($p \leq 0.05$), higher maximum velocity (7.944±1.087 & 7.786±0.915$m.s^{-1}$) ($p \leq 0.05$), and match intensity (73.7±11.7 & 72.0±11.2 m/min) for both the 1^{st} and 2^{nd} halves. Differences in secondary positional groups showed that halfbacks achieved the highest total distance (3566.9 ± 559.4m & 3053.9±1009.3m) ($p \leq 0.05$), match intensity (78.7±10.9 & 76.6±12.2 m/min) ($p \leq 0.05$), and meters covered within velocity zone three (412.2±84.4m & 348.4±93.0m) ($p \leq 0.05$) for the 1^{st} and 2^{nd} halves. Outside backs recorded the highest maximum velocity (8.501±1.417 & 8.270±1.066 $m.s^{-1}$) ($p \leq 0.05$), the most high speed meters (298.9±60.8 & 257.5±71.5m) ($p \leq 0.05$), the most meters within velocity zone four (183.1±37.3m & 153.5±38.3m) ($p \leq 0.05$) and velocity zone five (115.9±38.4m & 104.0±45.4m) ($p \leq 0.05$) for the 1^{st} and 2^{nd} half.

Physical preparation should reflect player match-play running performance demands of positional groups. Team and player conditioning and training sessions should focus on enhancing the specific running performance demands based on match-play data recorded. Future research should aim to establish more accurate positional groups, based on individual positional running demands, because literature differs on positional group demands. Researchers are resorting to grouping players into the primary positional groups, small and inconsistent subgroups, or reporting on the individual positions. Research may also lead to the development of accurate individualised velocity thresholds specific to positional groups. Improvements in technology and player tracking may further provide more accurate player data that will have to be assessed.

Keywords: rugby, strength and conditioning, GPS, match-play, velocity zones.

OPSOMMING

Rugby op universiteitsvlak is ŉ vinnige, hoë kontak sport. Die implementering van die Varsity Beker in Suid-Afrikaanse universiteite het die belangstelling in universiteit rugby dwarsoor die land aangewakker. Die hardloop eise waaraan universiteit rugby spelers tydens wedstryde blootgestel word, is nog nie deeglik nagevors nie. Verandering in rugby reëls en die veranderende taktiek van afrigters vereis nuwe metodes om prestasie uitkomste te bereik. Huidig is daar beperkte gepubliseerde navorsing oor Suid-Afrikaanse rugby op universiteitsvlak en die gebruik van totale afstand, hoëspoed meters, maksimale snelheid, wedstryd intensiteit, aantal versnellings en spoedverminderings en snelheidsones om die eie wat deur spelers tydens ’n wedstryd ervaar word, te analiseer. Die huidige studie was daarop gemik om die in-spel fisieke harloopvereistes tydens Suid-Afrikaanse universiteit rugby spelers uit te lig, deur van globale posisioneringstelsels (GPS) gebruik te maak.

Die eerste doelwit van die studie was om die in-spel hardloopvereistres van Suid-Afrikaanse universiteit rugby spelers met behulp van GPS, tydens wedstryde vir primêre en sekondêre posisionele groepe, te ondersoek. Die tweede doelwit was om die verskille in in-spel hardloopvereistes vir die primêre en sekondêre posisionele groepe tussen die 1ste en 2de helftes van wedstryde tydens die 2018 Varsity Beker rugby kompetisie, te bepaal. Die studie is volgens die artikel formaat saamgestel. Artikel een het die eerste doelwit en artikel twee het die tweede doelwit aangespreek.

Suid-Afrikaanse universiteit rugby spelers (N=40) verbonde aan twee universiteite is gedurende wedstryde met behulp van die GPS geassesseer. Die spelers is in twee primêre posisionele groepe verdeel, voorspelers (n=22) en agterspelers (n=18), en vyf sekondêre posisionele groepenaamlik: die vaste voorspelers (n=14); losvoorspelers (n=8); skakelpaar (n=5); binne agterspelers (n=6); en buite agterspelers (n=7). Die GPS analise het die volgende wedstryd bewegings voorsien: totale afstand; hoë-spoed meters afgelê; maksimum snelheid; wedstryd intensiteit; aant Drie verskillende wedstryd periodes was gebruik om die data te beskryf.

Die resultate van die eerste doelwit het verskille tussen die primêre posisionele groepe en die sekondêre posisionele groepe getoon. Agterspelers het beter resultate vir die

harloopvereistes in vergelyking met die voorspelers getoon. Skakelpare het die hoogste totale afstand (6620.9±784.4m) ($p \leq 0.05$) en wedstryd intensiteit (77.7±11.6m/min) ($p \leq 0.05$) aangetoon. Die buite agterspelers het die hoogste maksimale snelheid (8.385±1.242 $m.s^{-1}$) ($p \leq 0.05$) behaal. Losvoorspelers het die hoogste aantal versnellings (385.5±122.1) en spoedverminderings (378.7±108.1) aangetoon. Agterspelers het meer meters binne al drie snelheidsones behaal en was betekenisvol beter as die voorspelers ($p \leq 0.05$). Skakelpare het die meeste meters in snelheidsone drie aangeteken en buite agterspelers het die meeste meters in snelheidsones vier en vyf ($p \leq 0.05$). Die groepe het nie grootliks verskil in terme van die aantal versnellings en spoedverminderings tydens die volle wedstryd nie.

Die resultate van die tweede doelwit was soortgelyk aan die eerste doelwit. Die primêre agterspelers het beter resultate vir alle gemete statistieke vir beide die 1^{ste} en 2^{de} helftes aangeteken . Agterspelers het ŉ beter totale afstand (3313.8±602.5m & 2947.8±887.7m), hoëspoed meters (237.6±53m & 221.6 ± 64.6m) ($p \leq 0.05$), aantal versnellings (382.80±105.5 & 353.03±123.2) en spoedverminderings (378.6±85.4 & 344.9±107.4), totale afstand in al drie snelheidsones ($p \leq 0.05$), hoër maksimale snelheid (7.944±1.087 & 7.786±0.915$m.s^{-1}$) ($p \leq 0.05$) en wedstryd intensiteit (73.7±11.7 & 72.0±11.2 m/min) vir beide die 1^{ste} en 2^{de} helftes. Verskille in die sekondêre posisionele groepe het getoon dat skakelpare die beste totale afstand (3566.9 ± 559.4m & 3053.9±1009.3m) ($p \leq 0.05$), wedstryd intensiteit (78.7±10.9 & 76.6±12.2 m/min) ($p \leq 0.05$) en meters afgelê binne snelheidsone drie (412.2±84.4m & 348.4±93.0m) ($p \leq 0.05$) vir die 1^{ste} en 2^{de} helftes, behaal het. Buite agterspelers het die hoogste maksimale snelheid (8.501±1.417 & 8.270±1.066 $m.s^{-1}$) ($p \leq 0.05$), die meeste hoëspoed meters (298.9±60.8 & 257.5±71.5m) ($p \leq 0.05$), die meeste meters binne snelheidsone vier (183.1±37.3m & 153.5±38.3m) ($p \leq 0.05$) en snelheidsone vyf (115.9±38.4m & 104.0±45.4m) ($p \leq 0.05$) vir beide die 1^{ste} en 2^{de} helftes behaal het.

Fisieke voorbereiding moet die wedstryd hardloopprestasie vereistes van posisionele groepe reflekteer. Span en speler kondisionering en inoefeningsessies moet daarop fokus om die spesifieke hardloopprestasie vereistes, gebaseer op aangetekende wedstryd data, te verbeter. Toekomstige navorsing moet daarop gerig wees om meer akkurate posisionele groepe te vestig wat gebaseer is op individuele posisionele hardloop vereistes aangesien die literatuur verskil rakende posisionele groep vereistes. Navorsers groepeer spelers in die primêre posisionele groepe, klein en teenstrydige subgroepe, of rapporteer oor individuele posisies. Navorsing kan ook aanleiding gee tot die ontwikkeling van akkurate geïndividualiseerde snelheid drempels spesifiek tot posisionele groepe. Verbeterings in tegnologie en die naspeuring van spelers kan meer akkurate speler data tot gevolg hê wat geassesseer kan word.

Sleutelwoorde: rugby, krag en kondisionering, GPS, wedstrydspel, snelheidsones.

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LIST OF ABBREVIATIONS

GPS	Global Positioning System
HB	Half Backs
HSM	High Speed Meters
IB	Inside Backs
LF	Loose Forwards
M	Mean
NQF	National Qualifications Framework
OB	Outside Backs
SANZAR	South Africa, New Zealand and Australian Rugby
SAQA	South African Qualifications Authority
SARU	South African Rugby Union
SD	Standard Deviation
TD	Total Distance
TF	Tight Forwards
TMA	Time Motion Analysis
VC	Varsity Cup
WR	World Rugby

CHAPTER ONE

INTRODUCTION

This chapter is presented in accordance with the referencing guidelines of the Department Sport Science, Stellenbosch University.

THEORETICAL BACKGROUND

Rugby union (hereafter referred to as rugby) is a full contact sport with a combination of physically intense intermittent phases, involving high-speed collisions, interspersed by low-intensity periods. Rugby is ever-increasing in popularity, as well as the derivative forms of the game such as sevens, touch and tag rugby. Rugby is played by two teams of 15 players plus authorised replacements (eight at international level); with no more than 15 players from each team on the field at one time (Lindsay *et al*., 2015; World Rugby, 2017). There are various positions that players are able to play in. Positions are divided into two primary groups, namely forward players (forwards) and backline players (backs) according to their specific on-field roles where forwards are involved in physical contests to gain and retain possession, while backline players run in an attempt to invade opposition territory (Duthie *et al*., 2003; Cahill *et al*., 2013). The secondary positional groups analysed in the current study are separated into tight forwards (positions 1 to 5), loose forwards (positions 6 to 8), halfbacks (positions 9 & 10), inside backs (positions 12 & 13) and outside backs (positions 11, 14 &15). These positional groups will be discussed further in Chapter Two.

Rugby has frequently been a topic of research regarding the high impact collisions, physical demands and physiological changes during competitions and training. Since the sport turned professional in 1995, the physical and playing demands of rugby have increased and become more intense leading to stronger competition with players becoming heavier and taller, particularly the backline players (Quarrie *et al*., 2013; Vahed *et al*., 2014). These demands include more acceleratory events during match play where players often experience speeds of 5m.s^{-1} on average before a tackle collision (Hendricks *et al*., 2012). Players during rugby matches often achieve speeds of 8.6±0.7 ms^{-1} (McLellan *et al*., 2011) and >6.7 m.s^{-1} in open play (Roberts *et al*., 2008). Increases in speeds achieved can predominantly be attributed to changes in laws, promoting a running game, as well as improved match analysis, technology and player conditioning (Quarrie *et al*., 2013). Along with increased demands on players, demands vary with the position played (Cahill *et al*., 2003; Austin *et al*., 2011). To determine these position-specific characteristics, accurate methods to measure and assess the activities are required for player development.

Coaches and strength and conditioning coaches are always looking for new ways to track and quantify player and team performances during training and matches (Wisbey *et al*., 2010; Aughey, 2011). A traditional method of time-motion analysis (TMA), involves video recorded matches with post-match analyses using software to determine the match activities of players (Duthie *et al*., 2003). Post-match analyses of video-based recorded TMA, however, have proved to be time consuming (Owen *et al.*,2015; Duthie *et al.*, 2013).

A modern method used to quantify the on-field movement demands makes use of inbuilt micro technology, a recent development being the global positioning system (GPS) units (Owen *et al*., 2015). GPS systems have been developed and improved and became evermore reliable over time (Aughey, 2011). Subsequently, GPS units have become more accessible, smaller, lighter and less intrusive for the wearer of these units (Wisbey *et al*., 2009; Aughey, 2011; Owen *et al*., 2015;). Along with these improvements higher sampling rates with increased accuracy and reliability has been shown. The implementation of GPS units in tracking players have become almost common practice in elite team sports today, but has also filtered down to other environments, such as sport academies, universities and clubs. The reliability and validity of these units has led to a better representation of a player's physical demands (Barbero-Álvarez *et al*., 2010; Jennings *et al*., 2010; Waldron *et al*., 2011). Studies such as Gabbett (2015) noted the success of junior rugby teams who attain greater velocities and are able to maintain higher velocities during matches, where increased velocities reflected positive outcomes. The study highlights teams use of GPS velocity thresholds as absolute and not individualised which has been shown to increase running performance during match-play in junior rugby teams (Gabbett, 2015). In a systematic review and meta-analysis, Harper, Carling and Kiely (2019) reported that elite athletes (including rugby union and rugby sevens) were more capable of maintaining a higher frequency and magnitude of accelerations and decelerations than lower performing players (Harper, D.J., Carling, C. & Kiely, J., 2019).

Although GPS units have become more extensively used to determine the demands of rugby (Venter *et al*., 2011; Cahill *et al*., 2013; McLellan *et al*., 2013; Gabbett, 2015, Owen *et al*., 2015), rugby league (Austin & Kelly, 2013) and Australian football league (Wisbey *et al*., 2010), little research has been carried out that quantifies the acceleration and deceleration load placed on players. GPS has also been adopted by other sport codes, such as netball (Cormack *et al*., 2014), soccer (Mallo *et al*., 2015) and rugby variations (Barbero-Álvarez *et al*., 2010; Jennings *et al*., 2010; Waldron *et al*., 2011; Ross, Gill & Cronin, 2015). Many of the studies identified have utilised an array of features on the GPS units to measure performance.

This study will focus on a specific population, namely South African student rugby players. Although the focus of the current study is not the student athlete per se, it is worth noting that the study is conducted within the context of this specific population. Student rugby players as a population are subjected to numerous non-sporting demands, such as academics, tests and exam schedules on top of a rigid, strenuous training regimen (Watt & Moore, 2001) and travelling (Jolly, 2008). The possible increased demands placed on student rugby players may result in performance drops, either in academia or sport performance. These players are a unique population classified by their full-time commitment as university students that also participate in sport. Watt and Moore (2001) define college (university) student athletes as those who face all the challenges experienced by non-athletes, such as social adjustment, career exploration and intellectual growth and in addition they have their sporting commitments and the experiences that relate to participation. These student rugby players are expected to perform at the highest levels of competition in their respective positions, with many of these players being selected for elite provincial teams and academies.

Overall, reported literature highlights the impact of running demands on rugby match play. Teams with greater knowledge of their players’ match running demands could have a distinct advantage as planning can be better directed to the necessary match demands. Strength and conditioning coaches would be able to apply the necessary conditioning principles to manage the demands placed on players to maximise performance and reduce player injury risk.

PROBLEM STATEMENT

Rugby is a well-documented sport in terms of its physical and physiological demands at elite levels. Student players, however, are a unique and specifically under studied population in the field of published literature related to the demands of rugby. A large gap in literature has emerged separating the developmental players (such as high school players) and elite players, leaving most university players out of the scope. Due to a lack of research performance profiles of university rugby players, such profiles are essentially non-existent. The purpose of this study was to investigate positional specific running demands of South African rugby at university level during match-play. The study may provide clarity on the population and better understand the demands placed on student athletes during match-play using GPS.

RESEARCH QUESTIONS, AIMS, OBJECTIVES, AND HYPOTHESES

Research article one

Research question

Are there differences in in-match running demands between positional groups in South African university rugby players?

Research aim one

The first aim of the study was to investigate the in-match running demands of South African university rugby players by using GPS during match-play per primary and secondary positional groups.

Specific objective

The objective that guided data collection for research aim one was to determine, during the 2018 Varsity Cup rugby competition the running demands of the full match (with the use of GPS (Catapult minimax X4), for the primary and secondary positional groups, with regards to:

a. total distance covered (m);

b. total high-speed meters (m);
c. maximum velocity (m.s-1);
d. number of accelerations and decelerations;
e. match intensity (measured in m/min);
f. velocity zone three: (4.44 – 5.56 m.s-1);
g. velocity zone four: (5.56 – 6.94 m.s-1); and
h. velocity zone five (> 6.94 m.s-1).

Hypotheses

H_1: The in match running demands of forwards will be significantly less than the total distance covered, total high-speed meters, maximum velocity, match intensity, number of accelerations and declarations and the total distance covered in each velocity zone than the backs for the duration of match-play.

H_o: The in match running demands of forwards will not be significantly less than the total distance covered, total high-speed meters, maximum velocity, match intensity, number of accelerations and declarations and the total distance covered in each velocity zone than the backs for the duration of match-play the backs for the duration of match-play.

H_1: The total distance covered, total high-speed meters, maximum velocity, match intensity, number of accelerations and declarations and the total distance covered in each velocity zone of secondary positional groups will be significantly more for the half, inside and outside back groups than the tight and loose forward groups for the duration of match-play.

H_o: The total distance covered, total high-speed meters, maximum velocity, match intensity, number of accelerations and declarations and the total distance covered in each velocity zone of secondary positional groups will not be significantly more for the half, inside and outside back groups than the tight and loose forward groups for the duration of match-play.

Research article two

Research questions

i. Are there differences in the in-match running demands between the 1st and 2nd halves of matches during the Varsity Cup rugby competition?

ii. Are there differences in the in-match running demands of the primary and secondary positional groups between the 1st and 2nd halves of matches during the Varsity Cup rugby competition?

Aim

To determine differences in, in-match running demands of the primary and secondary positional groups between the 1st and 2nd halves of matches during the 2018 Varsity Cup rugby competition.

Objective

The objective that guided data collection for aim two was to determine, with the use of GPS (Catapult minimax X4) the in-match running demands for the 1st and 2nd halves of the 2018 Varsity Cup rugby competition for the primary and secondary positional groups, with regards to

a. total distance covered (m);
b. total high-speed meters (m);
c. maximum velocity (m.s-1);
d. number of accelerations and decelerations;
e. match intensity (measured in m/min);
f. velocity zone three: (4.44 – 5.56 m.s-1);
g. velocity zone four: (5.56 – 6.94 m.s-1); and
h. velocity zone five (> 6.94 m.s-1).

Hypotheses

H_1: Significant differences between primary positional groups will be found with regards to total distance covered, total high-speed meters, maximum velocity, match intensity, number of accelerations and declarations and the total distance covered in each velocity zone for 1st and 2nd halves.

H_o: Significant differences between primary positional groups will not be found with regards to total distance covered, total high-speed meters, maximum velocity, match intensity, number of accelerations and declarations and the total distance covered in each velocity zone for 1st and 2nd halves.

$H_{1:}$ Significant differences between secondary positional groups will be found with regards to total distance covered, total high-speed meters, maximum velocity, match intensity, number of accelerations and declarations and the total distance covered in each velocity zone for 1st and 2nd halves.

H_o: Significant differences between secondary positional groups will not be found with regards to total distance covered, total high-speed meters, maximum velocity, match intensity, number of accelerations and declarations and the total distance covered in each velocity zone for 1st and 2nd halves.

MOTIVATION FOR THE STUDY

Knowledge of the physical demands required of athletes during competition and in training is a fundamental requirement for strength and conditioning coaches to construct a conditioning programme catering for the specific demands of the sport (Gabbett *et al.*, 2012). The current study aimed to give strength and conditioning coaches an indication of the match specific positional running demands of South African university rugby players in order to develop and execute specific training sessions to maximise performance and produce favourable results. Performance profiling of players participating in university rugby is necessary to establish normative values, the performance profiles can assist strength and conditioning coaches in monitoring players' readiness for competition. Additionally, teams with the means to monitor training sessions can maximise performance and minimise injury risk through analysing player load. Repeated exposure to high speed running, accelerations and decelerations will increase injury risk and player load.

Attaining players match demands could possibly allow the coaching staff to analyse and determine player fitness and recovery, more importantly player recovery during match play (work: rest). The nature of the Varsity Cup competition (discussed in depth in chapter two), could identify match recovery as a critical factor in the score outcome of a game. Strength and conditioning coaches may use the competition data as a performance goal to be reached when the competition season approaches. This goal gives a clear standard of performance that can either be matched or improved upon as an aim for future planning.

Although not a focus of the study, player load monitoring from matches, may provide player wellness profiles for coaches to assess possible overtraining risks or fatigued players. Along with the player profiles, positional profiles and standards can be realised through the constant monitoring of players. Overall, players can be monitored and periodization plans can be directed towards managing players stresses, while optimising training and competition loads. The data gathered provides scientists and coaches with insight into the physical demands of rugby players and other sporting codes. Strength and conditioning coaches can analyse the data to plan current and future seasons to improve the effectiveness of programme designs, optimise recovery, as well as reducing injury occurrence and possible player burnout.

STRUCTURE OF THE THESIS

The thesis is presented in a research article format. The two research articles (Chapters four and five), were prepared according to the guidelines of the specific journals (Appendix C & D). Consequently, the referencing style used in the thesis will differ.

<u>Chapter One:</u> Introduction: The chapter is included herewith, and an adapted Harvard method of referencing is used in accordance with the guidelines of the Department of Sport Science, Stellenbosch University.

<u>Chapter Two:</u> Literature review: The chapter is included herewith, and an adapted Harvard method of reference is used in accordance with the guidelines of the Department Sport Science, Stellenbosch University.

<u>Chapter Three:</u> Methodology: The chapter is included herewith, and an adapted Harvard method of reference is used in accordance with the guidelines of the Department of Sport Science, Stellenbosch University.

<u>Chapter Four:</u> Research article one: In-match differences in running demands of South African university rugby players. This chapter is included herewith in accordance with the journal guidelines of Journal of Sports Sciences (included as Appendix C).

<u>Chapter Five:</u> Research article two: Positional differences in in-match running demands between the 1st and 2nd halves of the 2018 Varsity Cup rugby competition. This chapter is included herewith in accordance with the journal guidelines of Journal of Strength and Conditioning Research (included as Appendix D).

Chapter Six: Discussion, summary (conclusion), limitations and future research. The chapter is included herewith, and an adapted Harvard method of referencing is used in accordance with the guidelines of the Department of Sport Science, Stellenbosch University.

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CHAPTER TWO

LITERATURE REVIEW

Referencing within this chapter and the list of references has been done in accordance with the guidelines of the Department of Sport Science, Stellenbosch University.

INTRODUCTION

Rugby is an intermittent, high-intensity, collision sport characterised by physically intense phases of play and displays of speed, skill and strength (Lindsay *et al*., 2015). Rugby is a sport that can be played by all ages. It made its way into junior club rugby, schools, senior clubs and universities. The introduction of popular rugby competitions, such as Varsity Cup and Varsity Shield has added to the popularity and population of university student players (hereafter referred to as student players). These student players are a unique population partaking in a full-time schedule of lectures, tests and examinations, while concurrently train and compete at a high level (Watt & Moore III, 2001).

The increased demand to training, competing and managing academics has led to the need for monitoring players to assess sporting demands. Within the context of the current study, the focus will only be on the sporting demands specifically related to rugby players. Strength and conditioning coaches can track and monitor player demands through different variations of time motion analysis (TMA). Global positioning systems (GPS) have become more accessible and reliable forms of micro technologies and is widely adopted into monitoring and tracking of on-field training and match-play running demands (Owen *et al*., 2015). These GPS units allow strength and conditioning coaches to determine the players' overall and positional demands and adapt strength and conditioning training to the demands of match play (Aughey, 2011). Data gathered provides scientists and coaches with insight into the physical demands of rugby players and other sporting codes. Strength and conditioning coaches can analyse the data to plan current and future seasons to improve the effectiveness of programme designs (Tee *et al*., 2017), optimise recovery (Quarrie *et al*., 2017), as well as reducing injury occurrence (Gabbett & Ullah, 2012; Quarrie *et al*., 2017), and possible player burnout (Quarrie *et al*., 2017, Tee *et al*., 2017).

According to the researcher there is currently no published English literature available, which specifically focuses on running demands of student players using GPS. This chapter aims to review the available literature and to presented it in the following four sections: (1) an introduction to rugby, as well as its history and background in a South African context; (2) the physical demands of rugby and positional-specific requirements; (3) the use of TMA in player tracking; and (4) the implementation of player tracking and monitoring by strength and conditioning coaches.

RUGBY UNION

Background and the South African context

The commonly held belief of the founding of rugby dates back to 1832, when a school pupil named William Webb Ellis, picked a football up and began to run with it. This act of picking up the ball as opposed to kicking it, gave rugby its distinguishing feature as it is known today (Bolligelo, 2006; Richards, 2011). Many years later rugby continued to grow into an amateur sport and eventually became acknowledged as a professional sport in 1995 when players demanded remuneration. The formation of SANZAR (South Africa, New Zealand and Australia Rugby), currently known as Super Rugby has implemented professional competitions for growth in the sport (Higham & Hinch, 2003; Bolligelo, 2006; Lindsay *et al*., 2015).

Currently, World Rugby (previously the International Rugby Board until 2014), serves as the governing body of the game, which is played across five continents (World Rugby, 2019). Recent statistics indicate that there are approximately 9.1 million registered rugby players in 121 countries and that rugby is regarded as one of the world’s most popular collision sports (World Rugby, 2017). The traditional game of rugby is played by two teams of 15 players with eight substitute players (only at Varsity Cup [VC] and professional level), on the bench per team. The game duration for senior level players competing in the open category, U/20 and above is 80 minutes in total, playing two halves of 40 minutes separated by a ten-minute halftime period (World Rugby, 2017). The VC scoring system will be described in a later section, however, for normal rugby matches and competitions a try is awarded with five points and two extra points for the conversion and three points for a successful penalty kick and drop kick at goal (World Rugby, 2017).

South Africa (SA) has a rich history in the game of rugby. The national team has won three Rugby World Cup competitions (1995, 2007 and 2019) since its official re-admission to international rugby in 1992. The popularity of the sport and the subsequent Rugby World Cup wins might have led to an increase in participation of the sport in SA. The VC and

Varsity Shield rugby competitions were established in 2010 as platforms for the top university teams of SA to compete against one another.

Positional groups and positional demands

A rugby team is split up into two primary positional groups, namely forwards and backs. In each of these positional groups, the players are subdivided into specific positions. The forwards are positioned as either a prop, hooker, lock or loose forward, whereas the backs are either a scrum half, fly half, center, wing or fullback as indicated in Table 2.1. Traditionally, players in the specific positions are subject to specific roles that dictate their optimal body type for those specified positions. Quarrie and Hopkins (2007), Vahed *et al*. (2014) and Owen *et al*. (2015) reported on the weight increases of the backs over time. Lombard *et al*. (2015) researched the shift in body type of South African U/20 players over a 13-year period. In the thirteen-year period, the primary positional groups did not change in stature, however, significant increases in strength (50%), endurance (50%) and body mass (20%) is evident. Owen *et al*. (2015) noted players averaging a body mass of 101±13kg, while Darrall-Jones, Jones and Till (2015) noted weights of 79±12kg, 88±12kg and 98±10kg in under 16, 18 and 21 male rugby players. With numerous advancements in technology, tactics and the changing rules of the game, these player roles have been subject to change.

Table 2.1: **EXTENDED POSITIONAL GROUP EXPLANATION**

Jersey number	Position name	Primary positional group	Secondary positional groups
1	Loose-head prop	Forward	Tight five
2	Hooker	Forward	Tight five
3	Tight head prop	Forward	Tight five
4	Lock	Forward	Tight five
5	Lock	Forward	Tight five
6	Blind-side flank	Forward	Loose forwards
7	Open-side flank	Forward	Loose forwards
8	Eight man	Forward	Loose forwards
9	Scrumhalf	Back	Half backs
10	Fly half	Back	Half backs
11	Left winger	Back	Outside backs
12	Inside centre	Back	Inside backs
13	Outside centre	Back	Inside backs
14	Right winger	Back	Outside backs
15	Full back	Back	Outside backs

Lombard *et al*. (2015) state that the increase of ball in playtime, collisions and rucks could be an argument for the physical changes of players to meet the current game demands. Reardon *et al* (2017) and Pollard *et al*. (2018) report average match intensities of >116m/min during the time that the ball is in play. Research indicate a large percentage of time spent at lower intensities because average game demands hover around 68m/min (Reardon *et al*., 2017).

Forwards need to be strong and powerful because they compete in a higher number of total impact tackles, tackle assists, scrums, mauls and rucks on offense and defence than the backline players (Duthie *et al*., 2003; Lindsay *et al*., 2015). The physical demands of forwards implies that they should be typically larger in size compared to the backs (Deutsch *et al*., 2007; Cunniffe *et al*., 2009; Jarvis *et al*., 2009; Lindsay *et al*., 2015). Backline players cover more distance, run at higher speeds, are more agile and evasive than the forwards and they are generally smaller in stature, however, there are some notable shifts in the physical attributes of backs (Deustch *et al*., 2007; Cunniffe *et al*., 2009; Jarvis *et al*., 2009; Lindsay *et al*., 2015). These physical demands on backs imply that they carry the ball more in open space and advance their team with speed, skill and evasive running (Lindsay *et al*., 2015).

Varsity Cup (VC) rugby tournament

The VC is an annual tournament played by nine university teams in a round robin format over a period of 11 weeks, including finals. Once all the round robin matches have been played, the top four teams on the combined log play the knockout round matches (semi-final and finals) to determine the annual winner of the competition (FNB Varsity Cup, 2018).

The VC rugby tournament follows the same basic law structure as 15-man rugby, namely that the match is made up of two, 40-minute halves separated by a 10-minute halftime break. Included in each half of play is a two-minute break, referred to as the strategy break that comes into effect within two minutes of either side of the 20-minute mark in the half. Both teams are given one, two-minute strategy breaks during each half, whereby coaches can discuss strategic and tactical changes with the players. The on-field referee calls for the strategy break (FNB Varsity Cup, 2018).

Specific law changes that are unique to the VC tournament can affect player performances. Three distinct law changes were introduced, namely: 1) the strategy break; 2) the experimental scoring system; and 3) power play.

The International Rugby Board (IRB), currently known as World Rugby (Kraak et al., 2017), granted permission for an experimental scoring system to the VC tournament organizers in 2012. The experimental points system states that if an attacking drive begins within the attacking teams' own half and a try is scored, the team is awarded seven points with a successful conversion totaling nine points. Should the attacking team begin their drive within the opposition half, the normal scoring structure of five points for a try and another two for a successful conversion applies. These points are enforced by two field referees that indicate the possible points by using two signboards. The scoring system was implemented to encourage a try scoring culture and make university rugby into a spectacle for attendees (Kraak *et al*., 2017).

The final law addition is that of power play where one team is forced to have two backline players sit out for a single three-minute period during the match. A team can decide when they would like to take their power play and the positions in the opposition backline they would like to remove. However, a team must be in possession of the ball in order to activate the power play. Should a team not use their power play during the match the referee will take the last three minutes of the match as an automatic power play for the team that has yet used their power play (FNB Varsity Cup, 2018).

The VC has become a platform for testing new laws and game changes for South African rugby. These law changes have been an attempt to encourage running rugby and create a better viewing experience for the spectators (Kraak *et al*., 2017). The potential impact of the law changes and the changes in player demands have not yet been researched and no confident inferences can be made.

Student rugby players

Student rugby players are exposed to higher levels of stress from their academic program and sporting commitments, which may affect performance in either of the stressors. These rugby players can be defined as full time university students with a full academic program that partake in top-level sport at a university (Watt & Moore III, 2001). There is very limited published research on monitoring and tracking of student rugby players in SA.

The student athlete population are exposed to numerous stressors of being an elite athlete and a student. These stressors have the potential to become factors contributing to over training and possible burnout, affecting the athlete's performance on various levels

(Grobbelaar *et al*., 2010). The players are students first and attend universities to attain degrees. Grobbelaar *et al*. (2010) recommend the need for different player management strategies to combat these performance inhibitors. The researcher acknowledges the contribution of all demands to the holistic well-being and sport performance of student rugby players. It is not within the scope of the current study to elaborate on all the demands placed on student rugby players, as well as methods of holistically monitoring these players. There are several tools available for researchers and practitioners to assess and manage university-level student athletes' life and training demands. Lu *et al*. (2012) identified social and life stresses for student athletes and highlights different individual stresses experienced by student athletes, such as academic schedule, injuries, training adaptations and interpersonal relationships to name few. Lu *et al*. (2012) noted that stresses could possibly lead to increase injury occurrences, declines in performance and correlation to burnout.

The current study focused on determining physical training and match running demands of university-level rugby players in a specific competition to report on these demands as one factor contributing to a bigger picture. Match and training GPS tracking offers a practical and up to date method of assessing and monitoring student athletes' external physical demands.

The VC competition bylaws define a bona fide student as registered with a university for a registered qualification in higher education on the National Qualification Framework (NQF) of the South African Qualifications Authority (SAQA), where students must obtain 120 SAQA credits or NQF level 6. Students unable to fulfil this requirement and those above the age of 25 are illegible to take part in the Varsity Cup tournament. For the purpose of this study, student rugby players were defined as above.

PHYSICAL RUNNING DEMANDS OF RUGBY

Modern-day rugby is known for its high playing intensities (i.e., increased ball in playtime and speed of play), along with high injury rates of which both are directly associated with the level of contact rugby players endure (Murray *et al*., 2014; Read *et al*., 2018). Evidence suggests that rugby has become faster and more physically demanding because of law changes and the tactical approach taken by coaches (Lombard *et al*., 2015; Kraak *et al*., 2017; Jones *et al*., 2018). Mean body mass and height were reported on South African U/20 rugby players over a 13-year period where forwards weighed 99 ± 9kg and 108 ± 7kg on average on the first and last years of the study (Lombard *et al.*, 2015). Backs represented similar results moving from 74±10kg to 88±8kg on average with an average increase in height of ±10cm over the study period (Lombard *et al*., 2015). Venter *et al*. (2011) reported U/19 player anthropometric data where the average reported heights and weights were 183 ± 6cm and 89.8 ± 10.8kg respectively among players with an average age of 18.5 ± 0.5 years. Similarly, Austin *et al*. (2011) reported positional averages of Super 14 rugby union players, where height and weight were higher than those reported by Venter *et al.* (2011), although the youngest players were 23 ± 2years. Average weights between front row forwards for the two studies were 114 ± 14kg (Austin *et al.*, 2011) and 99.4 ± 4.9 kg (Venter *et al.*, 2011). It is not solely the trends of match play that are changing, but the physical characteristics of players too (Read *et al*., 2018). Lombard *et al.* (2015) further noted that players increases in speed, stamina and strength with increases in strength around 50% higher. Pollard *et al*. (2018) noted differences in players match intensity during ball in playtime where forwards and backs with an average full match intensity of 65.7 ± 3.8m/min and 69.7 ± 5.0m/min compared to their respective match intensities, while the ball was in play being 106.0 ± 5.6m/min and 111.4 ± 10.5m/min for forwards and backs respectively. This increase in intensity during ball in playtime can affect work to rest ratios and identifies a faster paced game when the ball is in play. Duthie *et al*. (2005) reported forwards having higher work to rest ratios than backs at 1:6 and 1:20, possibly because of high contact and close quarter's nature of the primary positional group.

Over time, rugby has been subject to various law changes to adapt and improve safety and gameplay for players. The changes in laws consequently have led to changes in tactics, and therefore, the demands on teams and specific positions during match play (Quarrie & Hopkins, 2007; Vahed *et al*., 2014). These positional demands that players had to fulfil required more monitoring of the players and specified conditioning to match the demands of the modern game (Austin *et al*., 2011; Cahill *et al*., 2013; Owen *et al*., 2015). The changes in physical demands has resulted in changes regarding body shape and size, as well as conditioning methods over time (Lombard *et al*., 2015).

Methods of data collection for physical running demands

Time-motion analysis (TMA) used to be a traditional method of analysis involving video-based recordings for retrospective analyses using software to determine player's main activities during either match play or training (Owen *et al*., 2015). TMA is, however, a time-consuming process and impractical for the demands of sport today. TMA has subsequently been replaced by micro technology of global positioning units, a modern method for quantifying player running demands (Owen *et al*., 2015). The global positioning system (GPS) have added another dimension to sport analytics and player performance tracking and monitoring, which will be discussed in depth in the following sections.

Global Positioning Systems (GPS)

TMA and the variables thereof, are specific to the type of data required by coaching staff. Key performance indicators, such as ball in playtime, or in the case of positive and negative tackles, or running meters are isolated from the full match picture (Dogramaci & Watsford, 2006). TMA differs from the use of GPS where all events during a match or training are recorded. For this reason, researchers are looking more into the use of GPS to quantify movement than the traditional time-consuming TMA (Cummins *et al*., 2013).

GPS has been widely adopted by not only athletes, but also the public in general. The adoption of GPS in wristwatch technology has led to an increase in knowledge and use of basic GPS technology. Sport specifically designed GPS units provide far more data for analysis and training use and has been used increasingly by team sport to provide comprehensive information about on-field performance in training and competition (Cummins *et al*., 2013).

Original GPS units only measured a limited number of metrics, such as speed, distance and player movement patterns. Higher sampling rates and the integration of the triaxle accelerometer has allowed for the measurement of work rate patterns and physical loads (Cummins *et al*., 2013).

Sampling rate refers to the number of geographical positions recorded per second that allow the GPS unit to track movement by connecting the spatial change of the unit over the different collected geographic positions (Jennings *et al*., 2010). The lower sampling rates of GPS devices affect the accuracy, reliability and validity of the GPS units tracking accuracy and ability (Jennings *et al*., 2010). Some of the first GPS units could only sample at 1Hz. As technology advanced, new and better GPS units have subsequently been released and made available. The newer units come in a 5Hz and 10Hz variant with new developments of a 15Hz unit (Johnston *et al*., 2014; Vickery *et al*., 2014; Rampinini *et al*., 2015). It is important to note that studies have found that higher sampling rate units results must be approached with caution, although error rates are significantly less, there is still some rate of error (Jennings *et al*., 2010; Cummins *et al*., 2013; Johnston *et al*., 2014; Vickery *et al*., 2014; Rampinini *et al*., 2015).

5Hz and 10Hz GPS units were released and the accuracy and reliability of the GPS units increased with the higher sampling rates. Jennings *et al*. (2010) compared the 1Hz and 5Hz GPS units over a set protocol to establish differences in reliability and validity for sport specific movements (change of direction, straight-line speed, etc.). It was reported that the 1Hz and 5Hz units presented no significant differences in numerous parameters of data collection. Accuracy during short sprints (<15m) with the larger sampling rate of the 5Hz unit showed to be more reliable as the duration of the testing protocol went on (Jennings *et al*., 2010). Reliability during straight-line movement at low speed (walking) and distance (10 to 20m) was higher for the lower sampling rate GPS. The 5Hz units, however, were more reliable at greater speeds and longer distances. The coefficient of variance (CV) for 20 to 40m sprints were 14.0 and 9.8 for the 1Hz and 5Hz units respectively (Jennings *et al*., 2010). As explained earlier a higher sampling rate means that more geographic positions will be recorded per second (sampling rate dependent), which provides a clearer picture of athlete movement over the course of the recorded time.

Rampinini *et al*. (2015) reported a 30 to 50% lower error rate when comparing the 5Hz to the 10Hz GPS unit for metrics, such as total distance (TD), high speed running (HSR) and very high-speed running (VHSR). Shorter movements, such as accelerations and decelerations, as well as side-to-side movements in team sport were not accurately tracked by both variations of units (Vickery *et al*., 2014; Rampinini *et al*., 2015). Rampinini *et al*. (2015) did, however, note that the nature of team sport might not provide a clear picture of sporting demands. Movements such as jumping, kicking and collisions were not recorded accurately suggesting that triaxle accelerometers need improvement.

Numerous published studies have examined the reliability and validity of GPS units (Jennings *et al*., 2010; Cummins *et al*., 2013; Johnston *et al*., 2014; Vickery *et al*., 2014; Rampinini *et al*, 2015), where different GPS units have been compared with the gold standards of measurement in each metric. The trundle wheel or tape measure for distance and timing gates or a speed gun for speed represent the gold standard for testing GPS systems. Consequently, some errors were found in the different sampling rates for 5Hz (Jennings *et al*., 2010; Rampinini *et al*., 2015) and 10Hz (Johnston *et al*, 2014). Reports have noted that the higher sampling units did prove more accurate than those with lower sampling rates, however, there were no significant differences in accuracy of high speed movements and rapid change of direction (COD) among the different sampling rates (Jennings *et al*., 2010; Johnston *et al*., 2014; Vickery et al.,2014; Rampinini *et al*., 2015).

Barbero-Álvarez *et al*. (2010) assessed the test-retest reliability and validity of 35-team sport players' (20 Physical Education students and 14 elite junior football players), repeat sprint ability (RSA) with a 1Hz GPS unit placed on the upper back of each participant. The GPS information was correlated with timing gates over 15 and 30m respectively. A strong correlation was found for peak speed measures and it was concluded that GPS has proved reliable and valid for the retest regarding repeat sprint ability (Barbero-Álvarez *et al*., 2010). The results suggest that GPS may be a valid and reliable alternative for tracking running performance in team sport although further studies are required. Another study by Jennings *et al*., (2010) assessed straight line and change of direction (COD) movements of team sport players over 10, 20 and 40m using both GPS units (1Hz and 5Hz) and timing gates. 20 Australian football players wore the various GPS units and completed a number of straight-line runs and a running circuit to simulate sport specific movements. Jennings *et al*. (2010) reported strong confidence intervals of ±90% and concluded that measurement accuracy decreased as the speed of locomotion increased and that an increased sampling rate has shown to increase reliability and validity. Jennings *et al*., (2010) further concluded that GPS may be limited to short, high intensity, straight-line efforts and efforts involving COD. Waldron *et al*. (2011) conducted a study on youth male rugby players on the test-retest reliability and validity for 10, 20 and 30m straight line speed using a 5Hz GPS unit. The mean speed reported a p value of < 0.05 and a coefficient of variation of 0.78% after a series of maximum sprint efforts by players. Discrepancies in results for the shorter distances led researchers to acknowledge that despite findings, the practical use of GPS units would be valid and reliable for team sport (Waldron *et al*., 2011). In the modern game, the use of GPS systems has increased as knowledge of the products and extensive testing has taken place (Jennings *et al*., 2010; Cummins et al., 2013).

Physical demands of rugby

Typical variable metrics analysed the general and position specific match-play physical demands including total distance covered, total high-speed meters and maximum velocity. Match intensity, also referred to in some literature as relative distance and number of accelerations and decelerations are also included, but not as frequently as the previously mentioned metrics. The aspects of each metric will be explained in detail in the sections that follow:

Total distance

Total distance (TD) has been a popular topic of discussion in the realm of GPS tracking in team sport, mainly outdoor sport. The TD metric was tested to be the most reliable, accurate and easy to measure because sampling rates are consistent among the of different sampling rates available in GPS units (Akenhead *et al*., 2014; Rampinini *et al.*, 2015). Elite team sport have adopted GPS technology and make use of a number of metrics available in the GPS software architecture.

Numerous studies conducted on rugby players (McLellan *et al*., 2011; Quarrie *et al*., 2013; Austin & Kelly, 2014; Reardon *et al*., 2015) have assessed the playing demands of both the groups and positions during match play. Quarrie *et al*. (2013) found some similarities between secondary positional groups. Other researchers reported on the primary positional groups of forwards and backs and reported results of 5964m±696m and 7628±744m (Austin & Kelly, 2014), 4982m±1185m and 5573m±1128m (McLellan *et al*., 2011) and 5638m±762m and 6171m ±767m (Reardon *et al*., 2015) for forwards and backs respectively. A tabulated comparison can be seen in Table 2.2.

Many of the reported results of elite rugby players show similarities within the distance covered by secondary positional groups, such as tight forwards (positions 1 to 5) (5000m ±886m), loose forwards (positions 6 to 8) (5100m ±855m), half backs (positions 9 & 10) (5756m ±915m), inside backs (positions 12 & 13) (5600m ±770m) and outside backs (positions 11, 14 & 15) (5950m ±755m) (Quarrie *et al*., 2013). The study by Venter *et al*. (2011) was based on a U/19 academy, which only represented the forward groups at 4672m ±215m for tight forwards and 4302m ±529m for loose forwards. This represents a large gap in distance travelled between the results of the elite forward groups reported by Quarrie *et al*. (2013).

High-speed meters

High-speed meters (HSM) has been reported differently in numerous studies involving movement tracking of athletes. Ross *et al*. (2015) classifies movement at high speeds for sevens rugby players in two zones, namely high-speed running (>4.16 $m.s^{-1}$), very high-speed running, which includes sprinting (>6 $m.s^{-1}$). In a similar study again with sevens rugby, high intensity running is registered at speeds >18.1km/h and sprinting was recorded when athletes entered speeds >20km/h (Suarez-Arrones *et al*., 2014). A study done by Quarrie *et al*. (2013) on international 15 man rugby displayed data recorded for high speed meters and sprinting at 6-8 $m.s^{-1}$ and >8 $m.s^{-1}$ respectively. Lastly, Rampinini *et al*. (2015) classifies high velocity movement as >4.17 $m.s^{-1}$ for soccer players.

As seen in Tables 2.2 and 2.3, there are numerous gaps in published research on position specificity regarding TD measurements in rugby. Through the articles mentioned in Table 2.3 above, it is possible to note how most researchers classify high-speed meters in two categories, namely high speed running and sprints. Some researchers do, however, also classify high speed running as distance covered above a certain threshold where all meters covered over a certain velocity/speed e.g. 5 $m.s^{-1}$ or 25km/h are classified as high-speed meters and subdivided into the two speed zones (Rampinini *et al*. 2015).

Few published articles (Table 2.4.) specify meters attained in recorded speed zones, but rather report on the velocity parameters and specify a maximum velocity/speed. An article published by Jones *et al*. (2015) provides an in-depth individual position profile of 33 rugby players. The data displayed in Table 2.4 indicate meters for each position above 5.0$m.s^{-1}$, which is what the author classified as high speed running (Jones *et al*., 2015). Reardon *et al*. (2015) also recorded 36 elite rugby players attempting to individualise speed zones for each individual position. As with Jones *et al*. (2015), HSM was recorded as any movement above 5$m.s^{-1}$ (Reardon *et al*., 2015)

High-speed meters covered is seldom reported in literature and could be an important part of rugby running profiles in terms of exerted effort during match play and training. Table 2.4 above represents the two relative studies found to date that record in depth the HSM of playing positions in rugby.

Table 2.2: **TOTAL DISTANCE COVERED BY PRIMARY POSITIONAL GROUPS IN PUBLISHED RESEARCH**

Authors	N=	Level	TD Forwards M±SD	TD Backline M±SD
McLellan *et al*. (2011)	22	Elite rugby league	4982m ± 1185m	5573m ± 1128m
Cahill *et al*.(2012)	98	Professional rugby union	5850m ± 1101m	6545m ± 1055m
Quarrie *et al*., 2013	763	Professional rugby players	5933 ± 708	5533 ±508m
Austin & Kelly, 2014	135	Professional rugby league	5964m ± 696	7628 ± 744m
Reardon *et al*., (2015)	36	Professional rugby players	5638m ± 762m	6171m ± 767m

Table 2.3: **TOTAL DISTANCE COVERED BY DIFFERENT SECONDARY POSITIONAL GROUPS FOUND IN PUBLISHED RESEARCH**

Author	n=	Level	TF M±SD	LF M±SD	HB M±SD	IB M±SD	OB M±SD
Venter *et al*., 2010	17	Under 19 Provincial players	4672m±215m	4302±529m		4307.78 ± 214m	4597.93 ± 210.18m
Cahill *et al*., 2012	98	Professional rugby union	5456m ± 1120m	6038 ± 924m	7098 ± 778m	6545 ± 841m	6278 ± 1371m
Quarrie *et al*., (2013)	763	Professional rugby players	5000m±886m	5100m±855m	5756m±915m	5600m±770m	5950m±755m

Table 2.4: **POSITIONAL GROUP TOTAL HIGH-SPEED METERAGE OF DIFFERENT POSITIONAL GROUPS IN PUBLISHED RESEARCH FOR RUGBY**

Author	Year	TF M±SD	LF M±SD	HB M±SD	IB M±SD	OB M±SD
Jones., *et al*.,	2015	146m±89m	306m±179m	381m±183m	587m±205m	566m±187m
Reardon *et al*.,	2015	334m±95m	387m±75m	448m±166m	588m±189m	628±120m

Maximum velocity/ Maximum speed

As a collision-based, high intensity, intermittent invasion sport, rugby players can achieve periods of sprinting or high velocity running (Lindsay *et al*., 2015). As mentioned in a previous section players could achieve velocities of greater than 20km/h or 4.16 $m.s^{-1}$ according to recorded literature (Suarrez-Arrones *et al*., 2014; Rampinini *et al*., 2015; Ross *et al*., 2015). Maximum speed or velocity is commonly recorded by modern GPS units and is generally frequently reported on as player demands in literature. Maximum velocities in rugby differ greatly between not only playing level, but also positional groups and individual positions (Quarrie *et al*., 2013). Backline players, specifically the Outside backs positions reach the highest velocities with the front row and tight forwards attaining the lowest scores (Austin *et al*., 2011; Quarrie *et al*., 2013). These results can be attributed to the nature of the positions where the forwards are subjected to a greater number of collision and contact situations during match play. This study will make use of different velocity zones, attempting to create an understanding of the running demands on student rugby players.

Although different from other team sport in terms of field dimensions and number of players, rugby seems to be comparable in terms of speed and velocity recorded during matches. Some reported research indicates that rugby players over different positions reach speeds above 9.0±0.2 $m \cdot s^{-1}$ (Duthie *et al*., 2006), 6.7 $m.s^{-1}$ (Roberts *et al*., 2008), 24km/h (Sirotic *et al*., 2009), and 8.6±0.7 $m \cdot s^{-1}$ (McLellan *et al*., 2011). Sevens Rugby players, however, attain maximum velocities of 8.1 ± 1.1 $m.s^{-1}$ (Higham *et al*., 2012). It must be noted, however, that sevens rugby is played over a shorter duration with more opportunities to attain higher maximum velocities because of the increased space available.

Other reported maximum velocities across a variety of sports are as follows. Soccer players attain speeds or velocities around, 25.43±3.13 km/h (Buchheit *et al*., 2014), field hockey players manage peak speeds of >7 $m.s^{-1}$ (Gabbett, 2010). Australian Rules Football (AFL), a similar variant to rugby, allows players to reach speeds in excess of 23km/h. Noted by various researchers, as a need for GPS tracking and monitoring, is the establishment of individualised speed/velocity zones to more accurately monitor player loads and running demands of match play (Cummins *et al*., 2013; Gabbett, 2015; Owen *et al*., 2015).

Accelerations and decelerations

The stop start nature of rugby has led to the need for a better understanding of acceleration and deceleration to minimise the risk of soft tissue injuries. There is a lack of published research on acceleration and deceleration in most contact and collision sports where the focus primarily highlights collisions and contact situations. Gabbett and Ullah (2012) noted that numerous bouts of increases and decreases into and out of high intensity running increases player's risk of soft tissue injury (95% CI). The reported data further explains that while the increased risk is present, players training at low intensities will fail to reach performance readiness if not subject to high intensity accelerations and decelerations (Gabbett & Ullah, 2012). Reviewed literature report that the majority of injuries are match related, non-contact, soft tissue injuries commonly bought about through running activity (Ball *et al*., 2017). Ball *et al*. (2017) summarised that in the available literature, inconsistencies in training and competition intensities exists and although players running at lower intensities were at less risk for soft-tissue injuries, their susceptibility to a non-contact injury may have been greater because of undertraining.

Accelerations and decelerations are a regular physical demand of sport and contribute to the overall physical load of athletes (Dalen *et al*., 2016). Dalen *et al*. (2016) noted in a study on soccer players that the sport, much like other team sport, involves periods of sudden bursts from low intensity to high intensity (acceleration) followed by braking (deceleration) and rapid changes of direction. It was observed that accelerations and decelerations contribute 7 to 10% and 5 to 7% respectively of total player load in soccer match play (Dalen *et al*., 2016). Hewit *et al*. (2011) highlight the need for understanding acceleratory loads during match play, because player movements requires acceleration and deceleration. The forces applied during these running movements contribute to the overall load of players and increase fatigue and, thus, the risk of injury (Hewit *et al*., 2011).

The acceleration and deceleration data collected by GPS units have possibly been used to understand sport specific match demands that may allow for team profiling. Examples could be such that a recorded match may have a greatly reduced TD compared to the previous match, but could have double the acceleration and deceleration counts. This increased acceleration and deceleration count could indicate a closer contact and collision match with less running in open spaces. Coupled with video analysis, coaching staff can adapt training plans accordingly. Although just a theory, no known research have been published on the uses of acceleration and deceleration data.

Match intensity

Measured as the average meters per minute (m/min), match intensity (also referred to as relative distance), is a calculated workload based on the overall distance travelled per minute by the players being tracked (Cummins *et al*., 2013). There is a large gap in published literature on match intensity because the metric itself has proven inconsistent with findings and requires further research. Limited research on match intensity for rugby opens a gap in the literature for future studies; however, other sports have some published research on match intensity. The systematic review by Cummins *et al*. (2013) only found one study reporting on elite rugby match intensity by Cunniffe *et al.* (2009). Cunniffe *et al.* (2009) reported values of 66.7 and 71.9 m/min for forwards and backs respectively.

Rugby league has a reported total match intensity of 106.0 ± 9.3 and 103.0 ± 8.1 m/min for elite and semi-elite players respectively (Sirotic *et al*., 2009). Junior rugby league players achieved between 75.4 ± 7.3 and 87.7 ± 9.0 m/min (Gabbett, 2015). Black and Gabbett (2014) reported other match intensity values of 91 ± 6 m/min in elite rugby league games. Cummins *et al*. (2013) in a systematic review of literature of an array of sport provides insight into match intensity. Reported match intensities for Australian Football League are 139.0 ± 11.1 m/min (Mooney *et al*., 2011) and 115.2 m/min for under 16 (U/16) soccer players (Harley *et al*. 2010). Higham *et al*. (2012) found that sevens rugby players covered 121 ± 16 m/min respectively.

Match intensity or relative intensity is able to give a quick overview of the demands of both training and match play providing an estimate of the overall running load of the sessions. As mentioned earlier, researchers have found it difficult to make positive inferences about match intensity because of the fluctuations between ball in play and rest times, where work rate has almost doubled (Pollard *et al.*, 2017). Practitioners may find it difficult to base training programs around the speed of a game that may dictate the intensity of players. Match intensity and ball in play should be topics researched in depth in future.

Velocity zones

Speed and velocity zones in terms of GPS tracking have been used interchangeably to describe player movement specifically pertaining to, but not exclusive to, sport with multidirectional movements. Gabbett (2015) used this velocity feature in team sport in order to establish relative speed zones that may increase high-speed running performance during match play. These zones are able to be individualised within the GPS units, either for individual players or established positional groups, providing more accurate measures of high intensity running for specific positions. Gabbett (2015) made note of GPS units not being individualised to players or positional groups for more accurate individual tracking during activity rather than overall absolute values for a team.

Various articles describe the use of speed zone metrics of measurement differently regarding the way speed is represented, where some research uses speed and others velocity to track player movement. Sirotic *et al*. (2011), Hingham *et al*. (2012), Quarrie *et al*. (2013) and Owen *et al*. (2015), referrer to the speed zone movement in an acceleratory format by measurements recorded in meters per second ($m.s^{-1}$), while Cunniffe *et al*. (2009), Coughlan *et al*. (2011), McLellan *et al*. (2011) and Granatelli *et al*. (2014) refer to speed zones as measured in kilometers per hour (km/h).

For the purposes of this study, velocity zones will refer to the player's movements as acceleratory ($m.s^{-1}$). Rugby being an intermittent, high intensity repeated effort sport in nature will be better represented in this research as acceleratory efforts. This context also supports the multidirectional accelerations within the sport itself, where measurements in km/h are more directed to straight-line or unobstructed movement.

Velocity zones are a metric used within the GPS unit that allows for the device to record movement velocity (measured in $m.s^{-1}$), when athletes accelerate or decelerate, or perform sport specific training and during match play. Integrated into the unit itself is a tri-axial accelerometer that registers movement data along a series of axis, along with the rate of sampling mentioned above to create velocity zones (Owen *et al*., 2015). Most GPS systems have a preset set of velocity zones, generally form zone one (1) to zone five (5) or six (6) with zone one being standing or low intensity movement and zone five being maximal sprint efforts. These zones can indicate impact and effort levels that provide further information on player demands (Cummins *et al*., 2013)

Exact velocity zone figures differ in each sport code and among various teams, where zone four (4) could be defined as a jog, run or high velocity depends on whoever has assigned the GPS units (Cummins *et al*., 2013). It has been noted that individual speed zones should be used among players to provide the most accurate individual results (Cummins *et al*., 2013, Gabbett, 2015). In cases of different playing positions with the same velocity zones, players appear to differ greatly, where the selected absolute velocities may be better represented by one secondary positional group, such as outside backs for high speed running meters compared to tight forwards who may not be able to reach these velocities as easily. Differing abilities of players in different positions, e.g. wingers, who attain higher max speeds are being compared against props because of the same preset velocity zones of the GPS units skewing data by a player's inability to attain certain speeds.

The use of these velocity zones can provide an indication of the intensities at which athletes move during competition. This indication could further assist coaches in directing training towards sport and competition specific demands. Gabbett (2015) noted that the use of relative speed zones increases the high-speed running performed in team sport. It was found that individualized speed zones relative to the athlete's capacity provide a more accurate depiction of his or her abilities, because of high-speed running meters contributing between 5.6 to 9.7% of the total distance of a given match (Gabbett, 2015).

As with player demands mentioned in previous sections the positional groupings will remain the same for the description of velocity zone information. The impact different positional groups may have on match play outcomes, based on the most predominant velocity zones in which the positional groups spend the most time or the ability to spread movement evenly among the different zones, has yet to be extensively researched or reported. Future research and intervention studies may be conducted in an attempt to increase player movement in a specific velocity zone for longer periods in order to increase player movement capacity, but this may be difficult to measure practically and in real time.

Positional demands have become a highlight in the field of Sport Science studies and have been found to be highly position specific (Austin *et al*., 2011; Cahill *et al*., 2013). Sirotic *et* *al*. (2011) made note of law changes affecting the overall speed, skill and physical demands of international rugby league players, along with the changes in tactics by coaches that may place additional demands on a positions' playing style.

THE USE OF GPS DATA IN STRENGTH AND CONDITIONING

The need for strength and conditioning coaches to have access to data indicating player demands during match play and training is highlighted by the attempts to cater specifically to each player in order to obtain the best adaptations to training programs.

Program design

Individual player training needs in a non-professional team may prove to be time consuming and impractical. Match play data allows for the creation of specific training modalities that emphasize the demands of competition, allowing players to be better prepared. Overload training through the specificity of match demands could be used to optimize training program design (Campbell *et al*., 2018). By using TMA and GPS, strength and conditioning coaches have a wealth of recorded data that creates an understanding of player movements, movement intensities and the overall movement demands of players both live and in retrospective analysis. Tee *et al*. (2018) mentioned teams, specifically rugby, making use of tactical periodization for designing programs and training sessions. This form of periodization becomes optimal in a team's approach to demonstrate training specificity (Tee *et al*., 2018). The approach to program design allows strength and conditioning coaches to adjust training sessions based on recorded training data from previous sessions. Training sessions that fail to achieve desired or planned outcomes can be adjusted to maximize performance and decrease injury risk (Tee *et al*., 2018). Season planning may be directed at achieving or exceeding the demands recorded from previous matches or seasons, leading to better long-term development of players and more accurate program designs.

Load monitoring

Practically, the recorded data could assist strength and conditioning coaches in quantifying player demands, creating training programs and monitoring player loads. Strength and conditioning coaches who make use of GPS systems for training are able to accurately track player movements during training and match play, as well as accurately plan sessions based on the recorded data. Cambell *et al*. (2018) reported greater total distance, low-intensity activity, match intensity and maximum velocities when compared to training. Owen *et al*. (2015) specified that forces experienced by players during match play, all impact on recovery time, injury risk and training planning. Consequently, players exhibit large discrepancies between match and training demands.

The aid of GPS in team sport and rugby specifically, identifies an increasing and changing platform for player monitoring and sporting demands along with accurately managing training loads for match preparation. Furthermore, training load-monitoring techniques, such as the use of player's rate of perceived exertion (RPE), can assist in maintaining optimal player loads for daily or weekly feedback. Comyns and Flanagan (2013) state the usefulness of RPE load monitoring for periodization planning based on principles of overload. RPE coupled with GPS data allows for more in-depth information on players and assist the strength and conditioning coaches to adjust training plans accordingly. Strength and conditioning coaches can be guided to not fall into the trap of overtraining by basing periodized plans exclusively on GPS data. Gabbett and Ullah (2012) note the relationship of running loads and soft tissue injury, and although low intensity running may have the lowest correlation to injury (13.1 per 1000 training hours), the effectiveness of these intensities is inadequate for performance. It must be mentioned that rugby as a collision sport does have some high instances of contact injury that more often than not cannot be prevented by training for match specific running demands.

In instances, such as acceleratory factors outlined by Owen *et al*. (2015), or the need for individualized speed zones by Gabbett (2015), GPS analysis by strength and conditioning coaches translates to practical changes affecting training. Overall, strength and conditioning coaches should aim to integrate the specific match demands recorded by GPS units into training programs that emulate the match demands. Running volume may firstly be addressed during preseason as players cover more total distance during this period rather than high intensity running (Gabbett & Ullah, 2012). Training sessions may then further shift from an overload in volume to an overload in running intensity during trainings, ultimately to be training under almost match specific conditions and could be integrated with work to rest ratios, such as those mentioned by Austin *et al*. (2011). Loads may be further monitored through the use of RPE to adjust the rate of overload that players are exposed to and adjustment of the periodized plan. A similar process can be followed for the secondary positional group demands, however, strength and conditioning coaches may have to more closely monitor the positional groups and make use of protocols, such ass maximal aerobic speed running to emulate and stimulate match demands during trainings.

Recovery

The information in the previous subsections can lead strength and conditioning coaches to implement effective recovery strategies based on the knowledge from both the type of training phase that teams are currently in and the internal and external load of players through the use of RPE calculations and the recorded GPS data (Rossi *et al*., 2017). Adjustments to the periodized plan and the expected load of training sessions can be conducted to assist the current team in terms of optimizing performance and future planning for teams based on the load achieved and the recovery strategy implemented to prevent instances of overtraining and burnout and reduce injury risk (Hamlin *et al*., 2012). Periodization for specific recovery exercises, drills, or complete training sessions may be planned and adjusted according to player response to training and effects from match play (Tee *et al*. 2018).

SUMMARY

The physical demands of playing in the VC rugby competition and managing a full academic program, as a registered, bona fide student at a top South African university requires good understanding and detailed monitoring of player demands. Students are exposed to numerous stressors that may affect match and training performance. Monitoring player matches and training loads has become common practice among coaching staff and teams who make use of numerous methods of TMA (Austin *et al*., 2011; Cahill *et al*., 2013; Gabbett, 2013; Owen *et al*., 2015). GPS is currently one of the more popular forms of player tracking and has allowed coaching staff to easily monitor and track players' external load during match play and training (Owen *et al*., 2015). Specific metrics have been identified and recorded because they are viewed as essential to the sport of rugby.

Although not a focus of this study, it would be unjust not to mention the various possible psychological demands that may change or influence the results of GPS data. Aside from the psychological stresses of classes and examinations, situations such as opponent quality (Gabbett, 2013), match situations (finals and semifinals, as well as relegation matches) and injuries could influence player efforts and GPS data capturing.

The purpose of this study was to investigate the position specific running demands of South African rugby at university level using GPS during match play. A description of player demands during competition identifying the in-match running demands of different positional groups of a rugby team may allow for specific training protocols to be implemented into team structures for player development and performance increases in competition.

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CHAPTER THREE

METHODOLOGY

This chapter is included herewith in accordance with the referencing style of the Department Sport Science, Stellenbosch University.

INTRODUCTION

A lack in current literature requests for an in-depth analysis of positional in-match running demands of university rugby players. This chapter will provide a breakdown of the way the study was carried out and the necessary particulars for it to be duplicated. This chapter will start by giving an overview of the study design, the participants' details, as well as the inclusion and exclusion criteria for sample selection. Mention is given to the relevant ethical aspects of the study. The study outline is covered with a focus on the place of study, matches monitored and data sources. After that, the data sources are elaborated on through the tests and measurements section, which describes the equipment used and procedures followed throughout the study. Outcome variables derived from the data are then listed and defined. Lastly, the methods of statistical analysis used to provide informative insight into the data are described. This chapter ends with a summary of the methodology of the study.

THEORETICAL PERSPECTIVES ON THE RESEARCH DESIGN

According to Peat and Barton (2005) research is a process for acquiring new knowledge in a systematic approach involving diligent planning and interventions for discovery or interpretation of newly gained information. Descriptive research is a general overview of a subject through observation and a description of its behaviour without any influence Grobbee (2004). Mouton (2011) concludes that research methodology describes the process that is followed by the primary researcher to conduct the research.

Bryman (2006) notes that the quantitative research process could be characterized by three concepts, namely: it is systematic; objective; and uses numerical data from a selected sub-group in order to generalize the findings to similar populations. It also gives researchers the ability to study variables differing in magnitude through a process of scientific and statistical analyses. It must be mentioned that a research project can only be commenced once ethical approval and informed consent were obtained from the relevant professional bodies.

STUDY DESIGN

The current study followed a descriptive design with no intervention, where positional in-match running demands were quantified during the 2018 Varsity Cup (VC) tournament. The group was monitored using GPS over a period of one competitive season of the VC (between February and April). GPS data were collected by the team's strength and conditioning coach. Data were grouped by primary and secondary positional groups then analysed in line with the study objectives.

PARTICIPANTS

The participants were recruited by contacting the management and coaching staff, attaining permission to make use of the teams to collect data. The informed consent forms were explained to and collected from the players. Players had the option to accept or reject the study and ethical clearance was attained. No pilot study was performed because of the lack of competition following the same format as the VC tournament. All the participants met the inclusion criteria with only nine (9) data sets being excluded because the players did not meet the required playing time during the specific matches. Player demographic information is displayed in Tale 3.1.

Table 3.1: **DEMOGRAPHIC INFORMATION OF PARTICIPANTS PER POSITIONAL GROUP**

Positional group(s)	n	Age (years)	Height (cm)	Weight (kg)	Observations (0-60 min)	Observations (60 - 80 min)
Forwards	22	20.75 ± 0.61	183.34 ± 1.04	101.24 ± 1.13	115	32
Backs	18	20.78 ± 0.06	177.02 ± 0.75	85.05 ± 0.52	109	15
Tight forwards	14	20.84 ± 1.36	183.10 ± 7.71	107.05 ± 8.83	68	26
Loose forwards	8	20.65 ± 2.58	183.58 ± 5.63	95.43 ± 6.57	47	6
Half backs	5	20.72 ± 1.48	175.22 ± 5.87	81.10 ± 7.68	30	6
Inside backs	6	20.67 ± 1.62	178.33 ± 4.05	88.43 ± 7.43	32	4
Outside backs	7	20.95 ± 1.57	177.50 ± 5.01	85.60 ± 8.64	47	5

The players were grouped according to the following positional groups: tight forwards (props, hookers and locks); loose forwards (flankers and eight men); halfbacks (scrum halves and fly halves); inside backs (centres); and outside backs (wingers and fullbacks). Similar positional groups have been recorded in a number of studies (Venter *et al.*, 2011; Quarrie *et al.*, 2013; Austin & Kelly, 2014; Lindsay *et al.*, 2015). Secondary positional groupings were selected in accordance of four of the five groups' studied by Owen *et al.* (2015) and Cahill *et al.* (2013) for tight forwards (TF), loose forwards (LF), inside backs (IB) and outside backs (OB). The current study grouped the scrum- and flyhalfs into one group, namely the half backs (HB) because studies by Quarrie *et al.* (2013) and Tee and Coopoo (2015), reported no significant differences between the two positions. The closest possible positional grouping was done by separating the players into four positional groups, similar to the groups established in the study by Owen *et al.* (2015); however, the current study separated the half-backs because it is believed that this position is highly specific and requires its own individual demand profile (King *et al*., 2009). This positional format allows data sets to be more easily managed and compared. This does not ignore that the positions have their own unique characteristics regarding size, strength, speed, etc. However, the allocated groups assumed that the positional groups would share similar results and demands based on previously recorded data. Although the literature on these groups has mainly dealt with professional level players, they are the only studies that relate to the student athlete population.

Inclusion and exclusion criteria

Players from the University of the Free State and the University of Johannesburg volunteered to participate in the study. These teams were selected because they were part of the VC competition and had access to 10Hz Catapult Minimax X4 GPS units. The teams consisted of 23 matchday squad members for the competition. The total number of participants for this study were 46 players. The players played a minimum of 8 matches per team (16 in total) during the 2018 competition. The two teams provided 23 player data points per match prior to the exclusion criteria, totalling 368 player data sets before the exclusion of data. Six (6) total datasets were excluded as inclusion criteria was not met.

The first requirement for inclusion in the study was access to 10Hz Catapult GPS units. Players had to be full-time male students from the two mentioned university teams participating in the 2018 VC competition. Players also had to hand in signed informed consent forms. Player data were excluded if less than 60 minutes of GPS data were recorded for a player. Players being subject to the powerplay rule were not excluded, because they were still part of the match but recorded little to no movement data during that time.

DATA COLLECTION

Data collection was undertaken for the 2018 VC season. The study made use of a commercially available Catapult GPS unit (Minimax X4, Catapult Innovations, Melbourne, Australia). Players were assigned a numbered unit according to the matchday team that was selected. The units were situated on the upper back of the players by a neoprene vest worn under their jerseys. Players were assigned a specific GPS unit to use for the duration of the competition. The GPS unit was placed into a pouch designed into the sport specific GPS vests that held the units between the shoulder blades on the upper back. The units were fitted by the team sport scientist prior to warm-up in order not to interfere with the match preparation of the coaching staff. The time of start and finish of each half and the whole match was recorded by the primary researcher to separate the extracted data.

Upon completion of a match, the units were removed from the vests and the data extracted. The data was processed using the official Catapult Openfield program (v.1.21.1) and extracted as a CSV format for use in Microsoft Excel. The GPS units were cleared and charged for the next match. Data was transferred to an external hard drive for storage and safety purposes. The raw data was categorised by team and match, with match data further categorised into first and second halves. Maximum speed, total high-speed meters covered, total distance covered, accelerations and decelerations and match intensity were further extracted for each player position. The necessary statistical calculations were established once the data was collected.

STATISTICAL ANALYSIS

Professor Martin Kidd from the Centre for Statistical Consultation at Stellenbosch University completed the statistical analysis. Statistica (version, 13.5.0.17) was used for the statistical analysis of the data (DELL INC. version 13.0.159.8). Participant information was described using descriptive statistics (mean ± standard deviation (SD). Mixed model ANOVA was used with “player”, “player* period” as random effects, and “position”,” period”,” position*period” as fixed effects. Fisher least significant difference (LSD) testing was used for post hoc testing. Normality assumptions were evaluated by inspecting normal probability plots and was mostly found to be acceptable. Participants were grouped according to playing position, broadly classified as forwards and backs and more specifically as tight forwards, loose forwards, half backs, inside backs and outside backs. Each grouping was analysed through three methods of interpretation: full match; and temporal pattern analysis. Given the normality of the data, parametric tests were conducted for statistical analysis. The level of significance was set at 95% ($p \leq 0.05$), with a lettering system (A, a-e) utilised to denote significant differences in figures and tables.

IMPLEMENTATION OF FINDINGS

The current study should provide valuable information to rugby governing bodies (VC) regarding the specific nature of the physical requirements placed on university rugby players during match play. The results should also provide strength and conditioning coaches and referees with valuable information that can assist with the development of physical programmes that are both individualised and specific.

Research article one: This article provides a description of the running demands of South African university rugby players during match play. Strength and conditioning coaches can assess the match data and adjust training programs to allow players to handle the possible stresses of tournament match play. Along with running demand stressors, players in different positions experience different levels of running demands because of the specificity of their positions. The article will describe the in match running demands of primary and secondary positional groups.

Research article two: This article provides a description of the differences in in-match primary and secondary positional running demands of university rugby players during the 2018 VC rugby competition over the 1st and 2nd half. Players were assessed using their in-match running demand metrics to identify possible differences within the primary and secondary positional groups for the 1st and 2nd half.

ETHICAL ASPECTS

The study protocol was approved by the Departmental Ethics Screening Committee (DESC) from Stellenbosch University and by the Research Committee for Humanities at the Free State University (reference number HS1043/2014) (Appendix B). The current research study contributes to a bigger multi- centre research project.

The study layout was verbally explained to the coaches and strength and conditioning coaches and players. Everyone involved were, therefore, aware of what the study entailed and what was required of them. Participation with wearing the GPS device was voluntary and all players were able to withdraw their data from the study at any time. All data were treated with strict confidentiality and remained anonymous when reported in the study. Coaches and strength and conditioning coaches had access to the raw data as per usually applied practices by the strength and conditioning coach of the team. Data was stored on a password-protected computer and on a protected file within the programs used to store the data. Hard copies were stored in a locked storeroom with an alarm system and with limited access at the Department of Sport Science at Stellenbosch University. The researcher and two supervisors had access to the data. The statistician who assisted with data analysis only worked with an anonymous coding system. Data will be kept for six years where after it will be shredded and destroyed, and electronic copies deleted. The goal is to publish two articles in which player data will be discussed and compared with the existing standards in literature. Only group data will be reported, and no player or team will be identified, unless there is written consent from the participants to review their data individually.

Participants were able to withdraw from the study at any point during the study. Their data will be protected and erased from all storage methods and excluded from analysis.

STUDY OUTLINE

The study monitored South African university players' match-play running demands over one competitive season. Data were gathered over a period of 10 weeks, providing data for 17 matches. The coaching staff selected the starting XV players of each week. Those that met the inclusion and exclusion criteria were monitored through GPS during match play. Data were collected and categorised into data sets according to set primary and secondary positional groups and analysed according to various periods of play. Matches were played on a Monday of each match week. Each match consisted of two scheduled 40-minute halves with a 10-minute break between halves. As per the laws of the competition there was also a mandatory two-minute strategy break in between each half called for by the on-field referee within two minutes either side of the 20-minute mark of each half. The experimental law mentioned in Chapter Two of the powerplay that can be taken during matches was also in effect. Chosen players form the opposing team were selected to sit out of the game for a three-minute period before returning to play. Players selected for the powerplays' data was included if the inclusion criteria were met. Seventeen matches were recorded over a 10-week period during the competitive season. Each team played a minimum of eight (8) matches with, one team making the semi-final play-off resulting in an extra fixture. Additional weeks with no matches were as a result of a bye.

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CHAPTER FOUR

RESEARCH ARTICLE ONE

IN-MATCH DIFFERENCES IN RUNNING PERFORMANCE OF SOUTH AFRICAN UNIVERSITY RUGBY PLAYERS

This article will be submitted for publication in the Journal of Sports Sciences. The article is included herewith in accordance with the guidelines for authors of this esteemed journal (Appendix C). However, to provide a neat and well-rounded final product for this thesis, the article has been edited to represent an actual published article, as it would appear in this particular journal. This does not imply that the article has been accepted or will be accepted for publication. Consequently, the referencing style used in this chapter may differ from that used in the other chapters of this thesis.

Title page

Title: In-match differences in running demands of South African university rugby players

Field of study: Sport Science

Running title: Running demands of university rugby players

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In-match differences in running demands of South African university rugby players

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ABSTRACT

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 demands of different playing positions during match play. The aim of the study was to investigate the in-match running demands of South African university rugby players by using the GPS during match play for primary and secondary positional groups. Total distance, maximum velocity, match intensity, total accelerations and decelerations, velocity zones for jogging, running and sprinting were selected as GPS metrics to best represent in-match running demands of rugby players. University players (N=40) from two universities that participated in the Varsity Cup rugby competition took part in the study. Players were fitted with GPS units and data was recorded for all matches played and match data was extracted. Halfbacks (HB) recorded the highest total distance (6620.9±784.4m) ($p \leq 0.05$) and match intensity (77.7±11.6 m/min) ($p \leq 0.05$). Outside backs (OB) recorded the highest maximum velocity (8.385 ± 1.242 $m.s^{-1}$) ($p \leq 0.05$). Loose forwards registered the highest number of accelerations (385.5 ± 122.1) and decelerations (378.7±108.1). Backs recorded more meters within all three velocity zones measured and were significantly higher than the forwards ($p \leq 0.05$). HB recorded the most meters jogging and OB recorded the most meters running and sprinting ($p \leq 0.05$). Backs and their specific subgroups play at and within high velocity thresholds, significantly higher than that of the forwards. Forwards tend to be involved in a higher amount of accelerations and decelerations during match play, suggesting that forward play is at close quarters to the opposition.

KEYWORDS: GPS, rugby union, positional groups, student athletes.

4.1. Introduction

Rugby union ('rugby'), an intermittent, high-intensity, collision sport, which is popular around the globe is characterised by physically intense phases of play, speed, skill and strength (Lindsay, Draper, Lewis, Gieseg & Gill, 2015). In South Africa, rugby is enjoyed by players of all ages (Harris & Wise, 2011). Universities in South Africa have become part of an intervarsity competition (Varsity Cup) that allows students to compete against one another on a semi-professional level. The Varsity Cup (VC) has expanded since starting in 2008 and has developed into a high intensity, high demand competition at university level. Another dimension to this competition is that participants are full time students and have a full academic program. Managing players to perform on all the demands of being a student athlete in South Africa has a large gap in published literature.

Since the onset of professionalism in 1995, the demands of rugby have increased and the game became more intense, resulting in players being heavier and the backs particularly became taller (Quarrie & Hopkins, 2007; Vahed, Kraak, & Venter, 2014). The number of impacts and impacts moving at high speed (McLellan, Lovell & Gass, 2011; Owen, Venter Du Toit & Kraak, 2015), and increased ball in playtime (Schoeman & Coetzee, 2014) have assisted in changing the demands of rugby. These increases are predominantly attributable to changes in laws, as well as improved match analysis, equipment technology and player conditioning (Quarrie & Hopkins, 2007). Along with increased demands on players, the demands differ per position played (Duthie, Pyne, & Hooper, 2003; Austin, Gabbett, & Jenkins, 2011; Cahill, Lamb, Worsfold, Headey, & Murray, 2013; Tee & Coopoo, 2015; Tee, Lambert & Coopoo, 2017). All players are required to perform core actions/activities, such as tackling and rucking during a match (Duthie *et al*., 2003), but the technical and tactical demands on players are different for the playing positions (Owen *et al*., 2015; Tee, *et al*., 2017). To determine these position-specific demands, accurate methods to quantify in-match running demands are required. 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 demands of different playing positions (Venter, Opperman & Opperman, 2011).

A modern method used to quantify these positional demands are through the use global positioning systems (GPS). GPS units have been used extensively to determine all demands of rugby (Cunniffe, Proctor, Baker & Davies, 2009; Venter *et al*., 2011; Cahill *et al*., 2013; McLellan *et al*., 2013; Jones, West, Crewther, Cook, Kilduff, 2015; Owen *et al*., 2015; Reardon, Tobin & Delahunt, 2015; Tee & Coopoo, 2015; Cunningham, Shearer, Drawer, Eager, Taylor, Cook & Kilduff, 2016; McLaren, Weston, Smith, Cramb & Portas, 2016; Tee *et al*., 2017; Yamamoto, Takemura, Kaya and Tsujita, 2017), and rugby league (Meir, Newton, Curtis, Fardell & Butler, 2001; Austin *et al*., 2011; Sirotic, Knowles, Catterick & Coutts, 2011; McLellan *et al*., 2011; Gabbett, Jenkins, & Abernethy, 2012; Gabbett, 2013; Cummins, Orr, O'Connor & West, 2013; Austin & Kelly, 2014) but little research has been carried out that quantifies the in-match running performance of university rugby players per positional group. It has been suggested that attention should be paid to the specific physical requirements of players from different playing positions to ensure that they receive adequate training stimuli (Tee *et al*., 2017).

Research on player's primary positional demands by Cunniffe *et al*. (2009) reveal that the total distances covered by elite rugby players per game by forwards were 6680m and 7227m by backs. Other studies confirmed that forwards accumulate 6680m (Cunniffe *et al*., 2009), 5850m (Cahill *et al*., 2013), 5370m (Cunningham *et al*., 2016) of total running distance respectively. The backs accumulated total running distances of 7227m (Cunniffe *et al*., 2009), 6545m (Cahill *et al*., 2013), and 6230m (Cunningham *et al*., 2016). The study by Austin *et al*. (2011) reported that the total distances covered by secondary positional groups during the Super Rugby tournament were: font row (4662±659m); back row (5262±131m); inside backs (6095±213m); and outside backs (4774±1017m). A study by Yamamoto *et al*., (2017) on Japanese professional rugby players revealed the distance covered for the front rows were (5604m); 2nd and 3rd row forwards (5690m), scrum-half's (7001m) and backs (6072m) respectively.

Reardon *et al*., (2015) reported match high-speed meters (HSM) of 290.35 ± 180.03m and 672.56 ± 181.20m for forwards and backs respectively. The tight forwards reported HSM of 157.4 ± 103.4m approximately, HSM for loose forwards were 452.8 ± 98.5m approximately, for half backs 549.5 ± 140.6m approximately, for inside backs 706.1 ± 208.6m and outside backs 783.8 ± 153.3m approximately (Reardon *et al*., 2015). The results of the study by Reardon *et al*., (2015) revealed 6.9 ± 0.6 and 7.9 ± 0.6 $m.s^{-1}$ for maximum velocity for forwards and backs respectively in a full match. The tight forwards recorded 6.7 ± 0.5$m.s^{-1}$, the loose forwards recorded 7.4 ± 0.2$m.s^{-1}$, the halfbacks recorded 7.7 ± 0.7$m.s^{-1}$, 8.0 ± 0.5$m.s^{-1}$ for the inside backs and 8.3 ± 0.4$m.s^{-1}$ for the outside backs (Reardon *et al*., 2015). Reardon *et al*. (2015) reported match intensities of 71.6 ± 10.14 and 81.0 ± 10.2 m/min for forwards and backs respectively for the duration of a full match. Match intensities reported values of 66.5 ± 6.5 m/min, 74.6 ± 6.5 m/min, 82.1 ± 5.2 m/min, 80.1 ± 2.4 m/min and 80.5 ± 2.2 m/min for tight forwards, loose forwards, half backs, inside backs and outside backs respectively (Reardon *et al*., 2015)

Owen *et al*. (2015) reported accelerations and decelerations for forwards and backs as 73 ± 31 and 82 ± 30 for accelerations and 80 ± 34 and 85 ± 32 for decelerations for only the 1st half of a professional rugby match. Secondary positional groups registered 62 ± 20 (tight forwards), 70 ± 28 (loose forwards), 90 ± 37 (scrumhalf), 85 ± 30 (inside backs, including flyhalf) and 75 ± 27 (outside backs) for accelerations approximately (Owen *et al*. 2015). Reported results for decelerations were 72 ± 26 (tight forwards), 83 ± 32 (loose forwards), 100 ± 40 (scrumhalf), 90 ± 30 (inside backs and flyhalf) and 76 ± 26 (outside backs) approximately (Owen *et al*., 2015).Limited literature has been reported on the number of accelerations and decelerations during full matches. Research on distance covered within different velocity zones varies because there is no agreed upon velocity thresholds for each zone particular to one sport or in general. Owen *et al*. (2015) made use of 1-1.99 m. s^{-1}, 2.0 – 2.99 m. s^{-1} and 3.0- >5.99 m. s^{-1} in three zones, whereas Quarrie *et al*. (2013) made use of six different velocity zones 0-2 m. s^{-1}, 2-2.3 m. s^{-1}, 3.5- 5 m. s^{-1}, 5-6 m. s^{-1} and >6 m. s^{-1}.

GPS uses wearable micro technology to record geographic positions over time and create a movement profile for players (Owen *et al*., 2015). Using this form of player movement analysis, individual external player loads can provide an indication of specific positional demands of these players. The purpose of any rugby specific physical training programme should be to optimally prepare players for the demands of match play (Owen *et al*., 2015; Tee, Ashford and Piggott, 2018). This can be achieved by maximizing training specificity through the manipulation of training activities to simulate or exceed the skill and physical demands of the match (Tee, Ashford and Piggott, 2018). Tee *et al*. (2018) noted that physical preparation should not be done in isolation, but with all the subsequent components for performance. Training sessions should be based around a combination of physical and mental aspects of the game that emulate match specificity, such as moving at high velocities and making decisions based on stimuli, such as defenders (Tee *et al*., 2018). Therefore, the aim of the current study was to investigate the in-match running demands of South African university rugby players by using GPS during match play for primary and secondary positional groups.

4.2. Materials and method

Participants

Male rugby players (N=40) from two South African universities competing in the 2018 VC rugby competition from February to April volunteered to partake in the study. A total of seventeen (N=17) matches were played between the two teams. All players were informed about the purpose of the study and gave informed consent before participating in the study. The participants' demographic information is displayed in Table 4.1. Participant data was excluded from the study if they played less than sixty minutes or the GPS device lost signal. A total of two hundred and seventy-one (N=271) observations were included based on the inclusion and exclusion criteria. The Sport Science Departmental Ethics Screening Committee (DESC) at Stellenbosch University and the Human Sciences Research Ethics Committee (HSREC) (UFS-HSD2017/0062) at the University of Free State approved the study.

Data collection procedure

Players from the two universities were fitted with Catapult minimax X4 10Hz GPS units for the matches. Each player was assigned a unit based on a team sheet for the match day. The GPS units were fitted in specialised neoprene vests designed specifically for the positioning and security of the GPS units on the player's upper back. The GPS unit was switched on prior to the start of the warm-up and was switch of after the match. The warm-up and half-time data were excluded and discarded. The data was analysed to identify information regarding player demands during match play in the primary and secondary positional groups. Data was extracted and split into the relative periods from the GPS units using the Catapult Open Field (v. 1.21.1) software. Data was extracted as a csv.file for further clean up in Microsoft Excel before being analysed in Statistica.

Table 4.1: Demographic information of participants per positional group

Positional group(s)	n	Age (years)	Height (cm)	Weight (kg)	Observations (0-60 min)	Observations (60 - 80 min)
Forwards	22	20.75 ± 0.61	183.34 ± 1.04^	101.24 ± 1.13^	115	32
Backs	18	20.78 ± 0.06	177.02 ± 0.75	85.05 ± 0.52	109	15
Tight forwards	14	20.84 ± 1.36	183.10 ± 7.71[cde]	107.05 ± 8.83[cde]	68	26
Loose forwards	8	20.65 ± 2.58	183.58 ± 5.63 [cde]	95.43 ± 6.57[cde]	47	6
Half backs	5	20.72 ± 1.48	175.22 ± 5.87	81.10 ± 7.68	30	6
Inside backs	6	20.67 ± 1.62	178.33 ± 4.05	88.43 ± 7.43	32	4
Outside backs	7	20.95 ± 1.57	177.50 ± 5.01	85.60 ± 8.64	47	5

Note: ^ denotes significant differences in weight between primary positional groups. [a] denotes significant differences when comparing tight forwards to other secondary positional groups. [b] denotes significant differences when comparing loose forwards to other secondary positional groups. [c] denotes significant differences when comparing half backs to other secondary positional groups. [d] denotes significant differences when comparing inside backs to other secondary positional groups. [e] denotes significant differences when comparing outside backs to other secondary positional groups ($p \leq 0.01$).

Positional groups

Players were grouped according to their playing position and split into the primary positional groups used by Cahill *et al*. (2013), namely forwards (loose-head prop, hooker, tight-head prop, locks, blind-side flanker, open-side flanker and eighth man), and backs (scrum-half, fly-half, left winger, inside centre, outside centre, right winger and fullback). The groupings selected were assumed to accurately reflect similar match demands for the playing positions and aid in comparison with previous research. The secondary positional grouping subdivided the team into five groups similar to the study by Owen *et al*. (2015). The five secondary positional groups for the current study consist of the tight forwards (TF) (loose head prop, hooker, tight-head prop and locks), loose forwards (LF) (blind-side flanker, open-side flanker and eighth-man), half backs (HB) (scrumhalf and fly half), inside backs (IB) (inside and outside centres) and outside backs (OB) (right- and left-wingers and fullbacks). The current study grouped the scrum and fly halves in one group into the HB as studied by Quarrie *et al*. (2013) and Tee and Coopoo (2015), who reported no significant differences between the scrum half and fly half positions.

In-match running demands variables

Total distance (m) describes the total number of meters covered by a player during the match. The metric is measured by the displacement of the GPS unit over time.

High-speed meters (m) refers to distance covered at high speed. For the purpose of the current study all meters run above 5.56 m. s^{-1} were registered as high-speed meters.

Maximum velocity (m. s^{-1}) achieved by a player during the full match. Maximum velocity is registered at the players peak running velocity.

Match intensity (m/min) reflects meters covered per minute. This metric is an internal calculation of the GPS software that determines the meters ran over the duration of the match and equates it as match intensity. Cummins, Orr, O’Connor and West (2013) similarly refer to relative distance (another reference to match intensity) as a calculated workload based on overall travelled distance per minute.

Number of accelerations (n) and decelerations (n) indicate a change in speed over the established velocity zones. Accelerations are registered because of increases in speed through the velocity zones and decelerations are recorded because of decreases in speed through the velocity zones.

Velocity zones three (4.44 to 5.54 $m.s^{-1}$), four (5.55 to 6.45 $m.s^{-1}$) and five (>6.46 $m.s^{-1}$) were indicative of the total distance covered within the velocity zones.

Data analysis

The Statistica 13 Data Processing package (DELL INC version 13.0.159.8) was used to process the data. Participant information was described by using descriptive statistics (mean [M] ± standard deviation [SD]). Mixed model ANOVA was used with “player”, “player* period” as random effects, and “position”,” period”,” position*period” as fixed effects. Fisher least significant difference (LSD) testing was used for post hoc testing. Normality assumptions were evaluated by inspecting normal probability plots and was mostly found to be acceptable. Participants were grouped according to primary and secondary positional groups.

4.3. Results

Total distance

The total distance covered per positional group and period is presented in Table 4.2. The results show that when comparing the forwards and backs no statistical significance between groups was revealed for the different periods. The HB covered the most distance during the full match (6620.9m), whereas the TF covered the least distance in the full match (5352.9m). When comparing the secondary positional groups, a statistically significant difference ($p \leq 0.05$) between the TF and the HB for the full match was observed, where HB covered more distance than TF.

High-speed meters

Table 4.2 presents the high-speed meters for the primary and secondary positional groups. The study revealed statistically significant differences when comparing the forwards and backs, with the backs recording better results ($p \leq 0.05$) across the duration of the match. The OB covered the most high-speed meters for the full match (556.450m), followed by the TF with the least high-speed meters for the full match (69.741m). When comparing the secondary positional groups, the results revealed a statistically significant difference ($p \leq 0.05$) between the TF who recorded less meters compared to the HB, IB and OB. When comparing the LF a statistically significant difference ($p \leq 0.05$) was revealed with the IB and OB having recorded more meters. The HB were significantly different ($p \leq 0.05$) from the TF (more meters), IB and OB (less meters). The comparison between the IB revealed a significant difference between IB and HB. The OB was statistically significantly ($p \leq 0.05$) different from all the other secondary positional groups having recorded the most meters at high speed.

Maximum velocity

Table 4.2 presents the maximum velocity of the primary and secondary positional groups for the recorded times. The results revealed statistically significant differences ($p \leq 0.05$) between the forwards and backs for full match play. The OB achieved the fastest maximum velocity and the TF the lowest for full match play. When comparing the secondary positional groups, the results revealed a statistically significant difference between the TF with all the other secondary positional groups. The LF were statistically significantly ($p \leq 0.05$) (7.129 ± 0.809 $m.s^{-1}$) different from the TF as higher values were recorded, however, the results were lower than the results recorded by the B and OB. The HB was significantly different ($p \leq 0.05$) (7.279 ± 0.866 $m.s^{-1}$) from the TF, IB and OB. The comparison of the IB revealed a significant difference between TF, LB and HB. The OB was statistical significantly different from all the other secondary positional groups because the group recorded the highest velocity, except when compared to the IB.

Match intensity

Match intensity, presented as average meters/minute, was higher for the backs than the forwards, but the difference was not statistically significant (Table 4.2). When comparing the secondary positional groups, the HBs indicated a statistically significantly higher average match intensity ($p \leq 0.05$) compared to the TF and OB during match play.

Number of accelerations and decelerations

There were no significant differences between the primary and secondary groups for the number of average accelerations and decelerations during match play.

Table 4.2: Positional demands for different variables per match time during the 2018 Varsity Cup tournament (M ± SD)

	Total distance (m)	**High speed meters (m)**	**Maximum velocity ($m.s^{-1}$)**	**Match intensity (m/min)**	**Accelerations (n)**	**Decelerations (n)**	**VZ^3 (4.45 – 5.56 $m.s^{-1}$)**	**VZ^4 (5.57 – 6.94 $m.s^{-1}$)**	**VZ^5 (>6.95 $m.s^{-1}$)**
Forwards	5734.4 ± 693.7	158.1 ± 30.8	6.598 ± 0.944	68.6 ± 9.5	363.8 ± 132.2	358.5 ± 117.7	197.4 ± 48.0	65.15 ± 24.5	27.9 ± 12.7
Backs	6261.6 ± 745.2	459.2 ± 58.7^	7.865 ± 1.001^	72.9 ± 11.4	367.9 ± 114.3	361.7 ± 96.4	305.3 ± 65.4^	158.3 ± 40.6^	71.5 ± 30.8^
Tight Forwards	5352.9 ± 798.6	69.7± 22.2	6,066 ± 1,079	66.8 ± 10.4	342.2 ± 142.3	338.4 ± 127.3	259.9 ± 43.7	61.2 ± 18.2	8.5 ± 7.8
Loose Forwards	6115.9 ± 588.8	246.4 ± 39.4	7.129 ± 0.809[a]	70.4 ± 8,5	385.5 ± 122.1	378.7 ± 108.1	529.5 ± 52.2[a]	199.2 ± 30.6[a]	47.2 ± 17.5[a]
Half Backs	6620.9 ± 784.4[a]	349.3 ± 54.5[a]	7.279 ± 0.866[a]	77.7 ± 11.6[ae]	366.0 ± 115.5	362.8 ± 98.8	760.6 ± 88.7[abde]	291.3 ± 46.4[a]	58.0 ± 18.6[a]
Inside Backs	6084.6 ± 779.4	471.9 ± 55.8[abc]	7.930 ± 0.895[abc]	71.2 ± 11.3	363.3 ± 116.2	356.5 ± 98.6	573.9 ± 57.5[a]	321.1 ± 37.6[a]	150.9 ± 31.9[ab]
Outside Backs	6079.5 ± 671.7	556.5 ± 65.8[abcd]	8.385 ± 1.242[abc]	69.7 ± 11.4	374.5 ± 111.2	365.9 ± 91.8	497.0± 49.8[a]	336.6 ± 37.8[ab]	219.9 ± 41.9[abc]

Note: ^ indicates significant differences between primary positional groups of forwards and backs for either the full match, first half, or second half periods respectively for the different metrics measured. [a]indicates significant differences between secondary positional groups when compared to tight forwards. [b]indicates significant differences between secondary positional groups when compared to loose forwards. [c] indicates significant differences between secondary positional groups when compared to halfbacks. [d] indicates significant differences between secondary positional groups when compared to inside backs. [e]indicates significant differences between secondary positional groups when compared to outside backs. VZ [3,4,5] refers to velocity zones three, four and five of the measured metrics. Statistical significance ($p \leq 0.05$)

Velocity zone three (4.45 – 5.56 m.s⁻¹)

Backs recorded significantly more meters within velocity zone three when compared to forwards for the duration of match play ($p \leq 0.05$). HB recorded the most meters within the zone (760.6 ± 88.7m) statistically significant ($p \leq 0.05$) from all other secondary positional groups. TF recorded the least meters within the velocity zone (259.9 ± 43.7m), significantly less than all other secondary positional groups ($p \leq 0.05$).

Velocity zone four (5.55 – 6.45 m.s⁻¹)

Significant differences ($p \leq 0.01$) were observed between the primary positional groups for velocity zone four. Forwards recorded significantly less distance when compared with backs within velocity zone four ($p \leq 0.01$). OB recorded the highest distance within velocity zone four and were significantly different from TF and LF. TF recorded the least distance in velocity zone four, significantly less than all the secondary positional groups. No significant differences were found between LF, HB and IB.

Velocity zone five (>6.46 m.s⁻¹)

Backs covered significantly more distance in velocity zone five when compared to forwards ($p \leq 0.01$). OB recorded the highest distance within the velocity zone, significantly higher than TF, LF and HB. IB recorded the second highest distance within velocity zone five, significantly higher than TF and LF groups ($p \leq 0.01$). TF recorded the least distance within this velocity zone, which was significantly less than all the other secondary positional groups.

4.4. Discussion

The aim of the study was to investigate the in-match running demands of South African university rugby players by using GPS during match play for primary and secondary positional groups. The research question was whether there were differences in the in-match running demands between positional groups in South African university rugby players?

The major findings of the study were as follows: backs recorded significantly greater results than forwards for metrics involving distance to be covered running, where they covered more total distance, high speed meters, meters in all velocity zones, higher match maximum velocity and match intensity and more accelerations and decelerations. The HB covered the most TD, significantly more than TF and more than all other secondary positional groups. HB also achieved the highest match intensity for the full match significantly more than all the secondary positional groups. The OB achieved the highest maximum velocity, significantly better than all other secondary positional groups for the full match. LF achieved the highest number of accelerations and decelerations for the full match. HB recorded the most meters covered in velocity zone three, significantly more than all other secondary positions. OB recorded the most meters in velocity zones four, significantly better than the TF and LF and five, significantly better than the TF, LF and HB. To date there were no studies published to the researcher's knowledge, which assessed the in-match difference in in-match running performance of South African university rugby player, which makes it difficult to make comparisons. Forwards were observed to be significantly heavier and taller than the backs ($p \leq 0.01$), this may be a possible reason for forwards recording lower results than backs for all the recorded metrics.

Total distance

The findings of the current study are similar to studies by McLellan *et al*. (2011) [elite level rugby league], Austin and Kelly (2014) [elite level rugby league], and Reardon *et al*. (2015) [elite rugby]. All these studies reported that backline players achieved a greater total distance covered than the forwards during matches. The studies mentioned followed similar trends of forwards covering less total distance than backs. Results differed only in the number of meters ran where younger players were participants. Venter *et al*. (2011) analysed under-19 players and reported a team average (4469.95m ± 292.25m). Venter *et al*. (2011) did, however, differ from the trend where front row forwards covered the most distance followed by the OB. Austin and Kelly (2014), however, found that players from both positional groups recorded higher total distance averages than those seen in similar studies, 7628 ± 744m and 5964 ± 696m for forwards and backs respectively. This may be because the study involved elite rugby league players, who played with only 13 players on a regulation-sized field. An earlier study by Austin *et al*. (2011) on Super 14 rugby players aligns with published research where backline players cover greater distances than forwards.

In the current study the HB recorded the highest total distance covered (6620.9 ± 784.4m) followed by LF (6115.9 ± 588.8m) on average, with the TF recording the least total distance in meters (5352.9 ± 798.5m). The HB group covered significantly more meters than the TF group for the full match. There were no significant differences between the HB and the remainder of the groups. This result is contrary to the findings of Quarrie *et al*. (2013), where OB groups achieved the greatest total distance (5950 ± 755m) followed by HB (5756 ± 915m). This result could be attributed to differences in sampling and grouping of players or the increased ball in playtime of the modern game. Austin *et al*. (2011) reported similar results to the findings of the current study. The study found that the IB achieved the greatest total distances; however, the study made use of four positional groups and combined the HB and IB groups. Venter *et al*. (2011) reported the total distance values for under 19 provincial forwards and found that the TF and LF recorded 4672m ±215m and 4302m ±529m respectively. The results for total distances covered vary to some degree among the literature available. Discrepancies, such as sampling, competition level and period of playing time in the case of Venter *et al*. (2011) could have influenced the results. Uncontrollable elements, such as the tactical planning of coaches and player fitness will also affect the accuracy of results during match play. Teams could have further been influenced by tournament laws, as may have been the case in the Varsity Cup where players may be forced to overcompensate for players that have been forced to sit out during the power play. Because of a lack of studies conducted on the population and the Varsity Cup competition itself, strong inferences cannot be made that the law changes influenced the total distances covered. The results of the player also do not differ greatly from what has already been reported in literature.

High-speed meters covered

There is limited available literature on HMS covered for primary positional groups. Reardon *et al*. (2015) reported 290.35 ± 180.03m and 672.56 ± 181.20m for forwards and backs respectively. The higher totals reported by Reardon *et al*. (2015) was possibly because the participants were elite rugby players. Possible reasons for the large differences could the inability of the TF to reach the minimum speed to register high-speed meters and the number of contact events involving in the TF. The results reported are similar to those reported by Reardon *et al*. (2015) where OB recorded the highest (628.43 ± 326.21m) and TF the lowest (333.64 ± 125.88m). Jones *et al*. (2015), however, noted that the IB covering the most meters at high-speed (587 ± 205m) and the TF covered the least meters (146 ± 89m). Both studies indicated that they made use of professional players for their data collection, where, player level, competition laws and coaching tactics may affect results of recorded data. Players exposed to HSM during training may be able to cope with match loads better when experiencing constant exposure to HSM. In the study by Reardon *et al*. (2015), the teams might have played a more running oriented game that allowed the forwards to register more meters covered, but still have the OB covering more meters at high speeds. Jones *et al*. (2015) possibly recorded teams where the tactic was to use the IB group to control the attacks through the middle of the field. Line breaks and higher numbers of phases could have contributed to the high number of meters by IB.

Maximum velocity (m. s^{-1})

Maximum velocity for the primary positional groups was significantly different for the full match, whereas literature reported that, the backs attained the highest scores. These results conform to current literature. Reardon *et al*. (2015) found that the backs achieved 7.94 ± 0.64 m. s^{-1} and forwards 6.89 ± 0.61 m. s^{-1} respectively. Duthie, Pyne, Marsh and Hooper (2006) analysed elite Super 12 rugby players. They reported that forwards achieved 8.4 ± 0.4 m. s^{-1} and backs 9.2 ± 0.3m. s^{-1}. Tee and Coopoo (2015) reported 7.6 ± 1.3 m. s^{-1} and 8.8 ± 1.1 m. s^{-1} for forwards and backs for South African professional rugby players. The results of the current study followed a trend indicating some consistency in recorded results. Differences in results could be determined by playing level and game plans where teams play to their advantages. No studies are known to disagree with the reported research above, however, there are differences in data values for the primary positional groups.

Reardon *et al*. (2015) reported individual positions maximum velocities. The OB positions (wingers and fullbacks) registered maximum velocities of 8.34 and 7.99 m. s^{-1} respectively. IB (centres) registered 8.05 m. s^{-1} (Reardon *et al*., 2015), which were lower than that of the OBs and it corresponds with the results of the current study. Owen *et al*. (2015) noted that forwards, because of their size and weight were not physically able to move at high speeds unlike the lighter smaller backline players. Forwards are also tactically used for their physicality and not necessarily speed. Another possible reason is the forwards involvement in set pieces and phase play, which is generally slow, while backs are often already moving when they receive the ball. Another notable point is the space within which both positional groups operate in. Backs are in more open playing field, while forwards are used physically in slower phase play.

Match intensity (m/min)

The backs recorded a higher average for the duration of the match. Cunniffe *et al*. (2009) reported similar findings with the backs recording 71.9 m/min. Reardon *et al*. (2015) reported averages of 71.61 ± 10.14 and 81.02 ± 10.20 m/min for forwards and backs respectively. These high averages may be attributed to the player level because the participants were elite professional players. Tee and Coopoo (2015), however, reported results that differ from other studies. In their study the players recorded 69 ± 8 and 69 ± 9 m/min for forwards and backs respectively (Tee & Coopoo, 2015), although not a large difference between the two groups, population fitness and game plan may have resulted in such close scores. The findings of current study follow a similar trend to current reported literature where backs covered more meters per minute compared to forwards.

The IB and LF recorded the second and third highest averages in the current study. The LF, IB and OB differed only slightly from each other across the match. This may be a result of the physical demands of each position, where the LF are involved in rucking, tackling and defensive work on a regular basis compared to the IB and OB who cover more distance in single bouts and at greater speeds, but less frequently.

There is limited research available for match intensity, especially regarding the secondary positional groups. A possible reason for this may be the practicality of the information, where coaches and researchers may not see the use of the data because they can analyse the total distance recorded, for example. Match intensity combined with match analysis statistics may be able to distinguish player work rate during matches. Coaches can analyse a player's effectiveness on the field after seeing a high match intensity recording from a GPS unit. Similarly, match intensity may offer an indication of player intensity during trainings providing an indication of intensity rather than only volume as in the case with total distance.

Number of accelerations and decelerations

There is limited literature on the number of accelerations and decelerations in rugby. Not widely reported, the current study recorded higher acceleration and deceleration counts compared to studies, such as that of Owen *et al*. (2015). Owen *et al*. (2015) reported an estimated 73±31 and 82±20 accelerations and 80±34 and 85±32 decelerations for forwards and backs respectively. However, only one-half of match-play was recorded in an attempt to increase the sample size. This large difference could be attributed to the measurement period used. Delaney, Cummins, Thornton and Duthie (2018) noted that the average velocities of most team sports were between 1.3–2.3 m. s^{-1} (low intensity), which question the ability of the players to accelerate and decelerate. Rugby as a stop start, high impact sport requiring players to accelerate and decelerate numerous times within matches was highlighted by the study on Super Rugby players by Owen *et al*. (2015). Although not recorded in the current study, the effect of contacts may have influenced the acceleration and deceleration data.

The constant effort to move contributes to fatigue during play, affecting the ability to perform (Hewit, Cronin, Button & Hume, 2011). A study by Dalen, Jørgen, Gertjan, Geir, Harvard and Ulrik (2016) that focus on accelerations and decelerations among soccer players highlights the physical strain of accelerating and decelerating on players. Markers such as acceleration, deceleration, mass and velocity provide player load (Dalen *et al*., 2016). It is unclear whether there are trends in the number of accelerations and decelerations. It is difficult to compare literature because researchers analyse different aspects of accelerating and decelerating, such as Hewit *et al*. (2011), Owen *et al*. (2015) and Delaney *et al*. (2018) who reported on the forcefulness of accelerating and decelerating. Assessing the number of accelerations and decelerations may provide an indication of match demands on players aiding in the implementation of soft tissue injury management strategies or adapted training to cope with the demands of matches.

Velocity zones three (4.44 – 5.54 m.s^{-1}), four (5.55 – 6.45 m.s^{-1}) and five (>6.46 m.s^{-1})

The backs and backs secondary groups outperformed both the forwards and forward secondary groups in terms of distance covered in all three zones for the duration of the match; this is in agreement with researched literature. HB covered the most distance in velocity zone three and OB in velocity zones four and five. Reardon *et al*. (2015) reported that scrumhalves and fly halves recording distances of 543.38 ± 232.80m and 571.41 ± 102.49m, which is less than the HB group in the current study. The experimental law changes in VC should be considered, where teams may play within these velocity zones in order to outpace opponents and benefit from the extra points on offer for scoring. Reardon *et al*. (2015) did, however, report on all meters covered >5.0 m. s^{-1}, lower velocities than the current study. Cahill *et al*. (2013) reported that scrumhalves registering 887 ± 607m, which is higher than the reported meters in the current study, which can be attributed to the groupings of positions because scrumhalves were identified as individual positions. Quarrie *et al.* (2015), however, reported values of non-significant or higher recorded metrics for flyhalf players when viewing individual position results; this could justify the selected positional groups of the current study. As mentioned by Cahill *et al*. (2013), Owen *et al*. (2015) and Tee, Lambert and Coopoo (2015), scrumhalf and fly half positions are constantly involved in set and phase play, often as the link between the forwards and backs providing context to the roles of the position.

Practical implications

Coaching staff in a university rugby environment can identify player demands during match play and focus efforts in these areas during training. Table 4.3 represents the positional recommendations for primary and secondary positional groups based on match recorded data. Season and session planning may be planned around it, or for priority matches and examination periods. Recorded data on player running demands may also provide an indication of player ability during match play, which could be paired with training data. Similarly, coaching staff may plan sessions or cancel sessions based on player load data, where specific session running demands increase player injury risk. Coaching sessions that may have yielded superior or inferior results than expected, could lead to changes in the planning of player training sessions. This form of player monitoring would ideally enhance the management of player loads. The possibility of individualized player profiles, or primary and secondary positional profiles can aid teams with the accuracy in which they prepare and execute training. Adjustments to velocity zones for the different positional groups can be done to accurately represent player ability during training. The recorded data above, paired with video analysis, could provide an even better indication of player movement and tactical impacts on playing positions for the future of rugby at university level in South Africa.

4.5 Conclusion

The results reported in this article follows the trend of published research available today. Most notably is the total distance covered and the match intensity recordings of the HB. Although the VC competition had a variety of law changes, the tactical aspects of rugby match play has been unaffected as results reported in this study do not differ significantly from reported literature. The competition took place from February to April noting that students did not take part in semester tests or examinations. As mentioned before, the involvement of the HB positions during a match may indicate the importance of conditioning in those specific positions for players to be able to handle the specific match loads. It is also important to note that no impact data has been recorded where such data might better describe the lower totals of the TF group who are involved in the set phases of play. Recorded data of the current study might serve as a steppingstone to in-match running demands within the South African university rugby context and stimulate further research on other aspects of this unique population and a changing game. Further research should be aimed at developing training programs catering for the demands of match play during training. These programs should be tailored to a specific metric, such as total distance or high-speed meters and the implications thereof.

Table 4.3: Practical applications and recommendations based on recorded match demands

Position	Results	Practical application
Forwards	Covered less total distance, a lower maximum velocity, lower match intensity and completed less accelerations and decelerations.	Focus on increasing overall fitness to improve total distance and match intensity scores. Expose the groups to a series of high intensity running protocols and construct games and drills that expose the forwards to extensive or prolonged running at a higher match intensity. Contact at higher match intensities could also be integrated into training to add more positional specificity of game demands to the conditioning of the position
Backs	Covered more total distance, attained a higher maximum velocity, had a higher match intensity and completed more accelerations and decelerations.	Focus on increasing overall fitness. Focus on ability to accelerate and decelerate safely and effectively from high velocity. Repeat exposure to high intensity and high speed running to avoid detraining effects. The implementation of repeat speed, maximal aerobic speed running and high intensity gameplay to further expose players that could result in overreaching on running demands.
Tight forwards	Covered the least total distance, attained the lowest maximum velocity, lowest match intensity and lowest accelerations and decelerations.	Focus on increasing overall fitness. Focus on improving ability to perform repeated outs of high intensity to assist with increasing match intensity. Maximal aerobic speed running and drills ensuring players are overloaded adequately to meet running demands during training. Variations in work to rest ratios and metabolic training such as tempo or lactate running could be used.
Loose forwards	Highest number of accelerations and decelerations. High total distance, maximum velocity and match intensity.	Focus on overall fitness Implement acceleration and deceleration strategies to expose players to high braking and acceleration loads. Repeat speed training to further expose players to forces of acceleration and deceleration to stimulate adaptations assisting the management of braking and accelerating forces on the body
Half backs	Highest total distance Highest match intensity	Focus on overall running fitness. Implement work to rest ratios within training to maximise running efficiency. Expose players to high training intensities to simulate match conditions through repeat speed, maximal aerobic speed and overspeed running.
Inside backs	High match intensity, maximum velocity and total distance	Focus on overall fitness. Focus on maintaining high running velocity over longer distances. Repeated bouts of high intensity running or repeat speed, while adjusting the work to rest ratios stimulating adaptations for consistent high-speed running.
Outside backs	Highest maximum velocity	Focus on overall fitness. Focus on high speed running to expose players to longer periods of high intensity running. Maximal speed running and repeat speed ability through varied rest periods during training can be implemented. The focus may be aimed at the quality of the speed meters are covered in rather than the distance.

Further research on player wellness during training demands spikes, or increased loads to simulate match conditions, which leads to another avenue to explore, namely player management. The limitations of this study were GPS units that malfunctioned, reducing the number of valid data points, a small sample size, recording only 17 matches; inconsistency in velocity zone threshold values among published literature and the current study did not record and report impact data.

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Disclosure statement

The authors reported no potential conflict of interest.

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CHAPTER FIVE

RESEARCH ARTICLE TWO

POSITIONAL DIFFERENCES IN IN-MATCH RUNNING DEMANDS BETWEEN THE 1ST AND 2ND HALVES OF THE 2018 VARSITY CUP RUGBY COMPETITION

This article will be submitted for publication in the Journal of Strength and Conditioning Research (Appendix D). The article is included herewith in accordance with the guidelines for authors of this esteemed journal. However, to provide a neat and well-rounded final product for this thesis, the article has been edited to represent an actual published article, as it would appear in this particular journal. This does not imply that the article has been accepted or will be accepted for publication. Consequently, the referencing style used in this chapter may differ from that used in the other chapters of this thesis.

Title page

Title: Positional differences in in-match running demands between the 1^{st} and 2^{nd} halves of the 2018 Varsity Cup rugby competition

Field of study: Sport Science

Running title: Positional running demands of university rugby players.

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Positional differences in in-match running demands between the 1st and 2nd halves of the 2018 Varsity Cup rugby competition

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Abstract

Rugby as a sport is characterized by players' abilities to move effectively and for prolonged periods. The aim of the study was to determine differences in in-match running demands of the primary and secondary positional groups between the 1st and 2nd halves of matches during the 2018 Varsity Cup (VC) rugby competition using global positioning systems (GPS). University rugby players (N=40) from two different universities participated in the study and were grouped by primary and secondary positional groups. The metrics measured provide an overview of in-match running demands of university players during the VC competition. The most notable results were found among the backs who recorded more total distance (3313.8 ± 602.5m & 2947.8 ± 887.7m), high speed meters, higher maximum velocity (7.944 ± 1.087 & 7.786 ± 0.915m.s^{-1}) ($p \leq 0.05$) and match intensity (73.7 ± 11.7 & 72.0 ± 11.2 m/min) for the 1st and 2nd haves. Differences in secondary positional groups showed half backs achieving the highest total distance (3566.9 ± 559.4m & 3053.9 ± 1009.3m) ($p \leq 0.05$) and match intensity (78.7 ± 10.9 & 76.6 ± 12.2 m/min) ($p \leq 0.05$) for the 1st and 2nd haves. Outside backs recorded the highest maximum velocity (8.501 ± 1.417 & 8.270 ± 1.066 m.s^{-1}) ($p \leq 0.05$) and the most high speed meters (298.9 ± 60.8 & 257.5 ± 71.5m) ($p \leq 0.05$). Positional and physical demands may influence a player's ability to achieve greater and more consistent results in running performance during each half of play. Strength and conditioning coaches may reflect on periodized plans for future planning to improve teams overall fitness and decrease the rate of fatigue or improve player recovery during the match through adaptations from training specificity and overload.

Key Words: Velocity zones, GPS, strength and conditioning, rugby

5.1 Introduction

Rugby as a collision sport played over a period of two halves, requires players to attain the ability to maintain match running demands for the duration of the match. Speed, strength and skill are basic requirements to be able to handle the physically intense game (1). Rugby in South Africa has become popularised and enjoyed by players and spectators as the country has experienced success in winning multiple world championships (2). South African universities became part of an intervarsity competition, the Varsity Cup (VC). VC has expanded in popularity after starting in 2008 and has become a platform for players to continue playing rugby as they pursue an academic degree in their chosen field. The demands of rugby have augmented with adaptive changes to the laws of the game (3), back players have become heavier and taller (4, 3), increased ball in play time (5) and impacts at high speeds increased (6, 7).

Players were divided into two primary positional groups, namely the forwards (1-8) and backs (9-15). Forwards are generally taller and heavier than backs because of their increased involvement in close quarters, physical positional playing demands (3, 4, 6). Primary positional groups can be further subdivided into positional groups that perform similar roles on the field in terms of match play demands (6, 8). Secondary positional groups such as tight forwards, loose forwards, half backs, inside backs and outside backs have been used in the current study to group positions with similar match demands. Owen *et al.* (6), Cahill *et al*. (9) and Duthie *et al.* (8) noted that individual positions show similarities in match demands, such as props, locks and hookers (tight forwards) and number of impacts, or high-speed meters by wingers and fullbacks (outside backs). Grouping players into specific positional groups can assist coaching staff in implementing training sessions that may be able to target the demands of multiple positions within one drill or exercise. Research on university populations and the demands on players during matches are sparse in published literature; furthermore, studies on rugby have focused mainly on physiological responses during full match play. Recording or analysing player movement in the past was often difficult and time-consuming methods of time motion analysis (6).

Advances in technology have made it possible to track player movements by using computer-based tracking systems and more commonly, micro sensor technology or global positioning systems (GPS) (6-14). GPS systems track athlete displacement over time for a specified period and have been proved accurate and reliable. GPS technology allows for reports on specified metrics, time and distance at specified velocities and the total distance covered within differing velocities (10). Recorded metrics of rugby match play assist in providing coaching staff with valuable information of external load placed on players during competitive play (11). The different metrics recorded using GPS can provide practical information with which to base and structure training programs that meet the demands of match play. Strength and conditioning coaches can make use of measured metrics, such as total distance, high-speed meters, match intensity and new metrics such as velocity zones (12) during match play to display the running demands placed on players. Players, however, can be substituted during the game for reasons such as fatigue or injury, this opens researchers to the differences in match demands of each half and the differences for the primary and secondary positional groups.

To date limited literature has been published on comparing the demands of players for the 1st and 2nd haves of match play. Differences in the measured metrics can indicate players possible rate of fatigue between both halves. Specific running demands recorded during games could provide insight into players conditioning and on field running demands within each half of play (6). Along with the more common metrics, such as total distance and high-speed meters (HSM), a study by Gabbett (12) noted that the use of relative speed zones during training and match play increases high-speed running performance in team sport. Players were observed to more accurately overload their running demands when using individualised relative speed zones when compared to absolute velocity zones. Gabbett (12) also refers to winning junior rugby teams covering more meters at high speeds when compared to losing teams. The use of velocity zones during training by strength and conditioning coaches focuses on increasing players' ability to train and play at higher speeds and velocities, leading to possible improvements in performance and results (12). Consequently, players who can maintain these running demands throughout each half can provide strength and conditioning coaches with information on the effectiveness of training programs that may specifically overload players in training to meet match demands.

Many team sports have adopted the use of GPS systems for monitoring during training and competition where players overall workload, running speeds, distance, etc., can be analysed post-match, in order to quantify player load and possible positional demands (12). Live player tracking can be conducted during training sessions and match play by monitoring the metrics used by the team, assessing the effectiveness and reliability of training programs that specifically aim to meet match demands. Previous research by Dwyer and Gabbett (14) attempted to identify the optimal velocity zones for team sport, however, rugby was not included in the study. Strength and conditioning coaches are responsible for the improvement and economization of player movements and their ability to accelerate and decelerate in multiple directions, while under pressure (14). As an evolving game, changes to the demands of positions within rugby has changed the time spent within acceleration zones and velocities as players become fitter and the game becomes faster (15). Delaney *et al*. (15) most notably mention that fullback positions cover the most distance at the highest velocities, where tight forwards experience the most accelerations and decelerations because of having less space for high velocity movement.

The current study article specifically focused on total distance (TD), high speed meters (HSM), match intensity, maximum velocity, number of accelerations and decelerations and the TD within three specified velocity zones of three (4.44-5.56 $m.s^{-1}$), four (5.56-6.96 $m.s^{-1}$), and five (>6.69 $m.s^{-1}$) of university rugby players over the 1st and 2nd halves of match play. This approach may provide an indication of the positional match play running and velocity demands of differing playing positions over the two halves of play that could allow strength and conditioning coaches to accommodate and adapt training schedules to cater for specific match play demands that players encounter.

Published research on differences between primary and secondary positional groups for the 1st and 2nd haves are sparse. Therefore, it is difficult to make confident inferences and comparisons when attempting to compare variables of TD, HSM, maximum velocity, match intensity, number of accelerations and decelerations and the distances covered within the three velocity zones.

The aim of the study was to determine the differences in in-match running demands for university rugby players in primary and secondary positional groups for the 1st and 2nd halves. This could bring light to topics that have shown inconsistencies in published literature, such as inclusion times for player data, the effects of substitutions and the demands of players substituted. The study by Vahed, Kraak and Venter, (3) highlights the importance of analysing rugby matches in the two separate halves when comparing physical profiles. Combining the data of both halves can still identify significant differences, but the differences found may only have been contributed by a change in one half and not the other. Strength and conditioning coaches can be directed by the information to implement sport specific training sessions that meet the demands of each half of play. Tactical changes made by coaches could indicate the necessity to understand player effectiveness in the 1st and 2nd half.

5.2 Methods

Participants

Male rugby players (N=40) from two South African universities competing in the 2018 Varsity Cup rugby competition met the inclusion criteria and agreed to partake in the data collection by providing informed consent. Seventeen (N=17) matches were recorded between the two participating universities. The participants' demographic information is displayed in Table 5.1. Participant data was excluded from the study if they played less than sixty minutes, teams not making use of a Catapult minimax X4 GPS unit and teams not participating in the Varsity Cup competition. Two hundred and seventy-one (N=271) observations (data sets), based on the inclusion and exclusion criteria, were included. The University of Stellenbosch Human Sciences Research Ethics Committee (HSREC) (UFS-HSD2017/0062) approved the study.

Table 5.1: Demographic information of participants per positional group.

Positional group(s)	n	Age (years)	Height (cm)	Weight (kg)	Observations (0-60 min)	Observations (60 - 80 min)
Forwards	22	20.75 ± 0.61	183.34 ± 1.04 ^	101.24 ± 1.13 ^	115	32
Backs	18	20.78 ± 0.06	177.02 ± 0.75	85.05 ± 0.52	109	15
Tight forwards	14	20.84 ± 1.36	183.10 ± 7.71^{cde}	107.05 ± 8.83 ^{cde}	68	26
Loose forwards	8	20.65 ± 2.58	183.58 ± 5.63 ^{cde}	95.43 ± 6.57 ^{cde}	47	6
Half backs	5	20.72 ± 1.48	175.22 ± 5.87	81.10 ± 7.68	30	6
Inside backs	6	20.67 ± 1.62	178.33 ± 4.05	88.43 ± 7.43	32	4
Outside backs	7	20.95 ± 1.57	177.50 ± 5.01	85.60 ± 8.64	47	5

Note: ^denotes significant differences in weight between primary positional groups. ^{a}denotes significant differences when comparing tight forwards to other secondary positional groups. ^{b}denotes significant differences when comparing loose forwards to other secondary positional groups. ^{c}denotes significant differences when comparing half backs to other secondary positional groups. ^{d}denotes significant differences when comparing inside backs to other secondary positional groups. ^{e}denotes significant differences when comparing outside backs to other secondary positional groups ($p \leq 0.01$).

Data collection

The university teams used Catapult minimax X4 10Hz GPS units that collected data during the Varsity Cup rugby competition. Players were given GPS units specifically assigned to a position on the playing field. The units were fitted using specialised neoprene vests designed specifically for the positioning and security of the GPS units on the player's upper back. Data were collected for the duration of Varsity Cup matches with warm-up and half-time data excluded and discarded. Data was extracted and split into the relative periods from the GPS units using the Catapult Open Field (v. 1.21.1) software. The data was then further analysed to identify information for player demands during match play for different positions. The data was extracted as a csv.file for further clean up in Microsoft Excel before being analysed in Statistica. Data were excluded if players played less than 60 minutes. The recorded metrics of the primary positional groups and secondary positional groups were extracted.

Primary positional groups similar to Owen *et al*. (6) were used. Secondary positional groupings were selected in accordance with four of the five groups studied by Owen *et al*. (6) and Cahill *et al*. (9) for tight forwards (TF), loose forwards (LF), inside backs (IB) and outside backs (OB). The current study grouped the scrumhalf and fly half in one group, the halfbacks (HB), because Quarrie *et al*. (4) and Tee and Coopoo (16) reported no significant differences between the two positions.

The in-match running demands variables used in the current study was as follows:

a. total distance covered (m);
b. total high-speed distance covered (m);
c. maximum velocity (m.s-1);
d. number of accelerations and decelerations.
e. match intensity (measured in m/min);
f. velocity zone three (4.44 – 5.56 m.s-1);
g. velocity zone four (5.56 – 6.94 m.s-1); and
h. velocity zone five (> 6.94 m.s-1).

Data analysis

The Statistica data processing package (Statsoft Inc., 2016) was used to process the data. Descriptive data was reported as means (M) ± standard deviations (SD). Mixed model ANOVA was used with “player”, “player*period” as random effects, and “position”, “period”, “position*period” as fixed effects. Fisher least significant difference (LSD) testing was used for post hoc testing. Normality assumptions were evaluated by inspecting normal probability plots, which were mostly found to be acceptable. Each positional group was analysed through two methods of interpretation: 1st and 2nd half.

5.3 Results

Reported results of primary and secondary positional groups were for TD, HSM, maximum velocity, match intensity, number of accelerations and decelerations and meters covered within velocity zone three, four and five. The results of the study for each positional group and half are presented in Table 5.2. Differences were observed between the 1st and 2nd halves of play. Both the primary and secondary positional groups generally showed a decline in all the metrics during the 2nd half.

Total distance

In the primary positional groups, backs covered more distance in both the 1st (3313.8 ± 602.5) and 2nd halves (2947.8 ± 887.7), but not significantly different ($p \leq 0.05$) from forwards who recorded distances of 3089.0 ± 560.4 and 2645.4 ± 826.9 for the 1st and 2nd halves respectively. HB recorded the highest total distance for the 1st (3566.9 ± 559.4) and 2nd half (3053.9 ± 1009.3), significantly better than only the TF group. TF recorded the least total distance for the 1st and 2nd halves.

High speed meters

Table 5.2 presents the high-speed meters for the primary and secondary positional groups. The results revealed statistically significant differences when comparing the forwards and backs ($p \leq 0.05$) across the two halves. When comparing the secondary positional groups, the results revealed a statistically significant difference ($p \leq 0.05$) between the TF compared to the HB, IB and OB regarding HSM. A statistically significant difference ($p \leq 0.05$) regarding HSM was revealed when comparing LF with the IB and OB. The HB were significantly different ($p \leq 0.05$) recording better HSM than the TF and less HSM than the IB and OB. The comparison between the IB revealed a significant difference between ($p \leq 0.05$) the IB and HB. The OB was statistically significantly ($p \leq 0.05$) better than all the other secondary positional groups regarding HSM.

Maximum velocity

Backs registered significantly higher ($p \leq 0.05$) maximum velocities in both the 1st (7.944 ± 1.087) and 2nd halves (7.786 ± 0.915) when compared with the forwards. OB registered the highest maximum velocities in both the 1st (8.501 ± 1.417) and 2nd halves (8.270 ± 1.066), significantly higher than the TF, LF and HB secondary groups. IB registered the second highest maximum velocity for the 1st and 2nd halves, significantly higher ($p \leq 0.05$) than the TF and LF groups for the 1st half, and higher than the TF, LF and HB for the 2nd half. LF and HB registered significantly higher ($p \leq 0.05$) maximum velocities compared to the TF who registered the lowest maximum velocity for the 1st and 2nd half.

Match intensity

Forwards recorded lower match intensity (69.7 ± 8.0 and 67.5 ± 10.9) when compared to backs (73.7 ± 11.7 and 72.0 ± 11.2m/min), however, no significant differences were observed between the primary positional groups for the 1st and 2nd half. The HB recorded the highest match intensity for the 1st (78.7 ± 10.9) and 2nd half (76.6 ± 12.2). This was significantly different ($p \leq 0.05$) from the TF and OB for both the 1st and 2nd half.

Number of accelerations and decelerations

No significant differences were found among primary and secondary positional groups for the 1st and 2nd half. Forwards recorded more accelerations and decelerations in the 1st half, while backs recorded more in the 2nd half. The LF recorded the highest number of accelerations and decelerations for both the 1st and 2nd half. The TF recorded the lowest accelerations and decelerations for both halves. Full results presented in Tale 5.2.

Velocity zone three (4.44 – 5.56 m.s^{-1})

Backs recorded a greater total distance for velocity zone three and recorded significantly ($p < 0.05$) more meters than the forwards for the 1st (328.8 ± 61.4m) and 2nd half (281.7 ± 69.3m). Among the secondary positional groups, the HB group achieved the highest number of meters and was significantly better than the remaining groups for the 1st (412.3 ± 84.4m) and 2nd half (348.4 ± 92.9m). The TF recorded the least meters within velocity zone three and all remaining secondary positional groups were significantly better in the 1st and 2nd halves when compared with the TF

Velocity zone four (5.56 – 6.94 m.s^{-1})

Backs covered more meters and were significantly different from the forwards for the 1st half (497.61 ± 38.20m) and 2nd half (451.31 ± 42.94m). The OB recorded the most meters covered within this velocity zone and were significantly better than the TF and LF groups for the 1st half (183.05 ± 37.29m) and 2nd half (153.54 ± 38.25). The HB and IB were significantly better than the TF for the 1st and 2nd half. The IB recorded the most meters covered during the 2nd half (156.97 ± 37.15m) and were significantly better than the TF and LF.

Velocity zone five (>6.64 m.s⁻¹)

Backs recorded more meters covered within this velocity zone and were significantly better ($p<0.05$) than the forwards for the 1st half (215.11 ± 28.33m) and 2nd half (213.57 ± 33.25m). The OB recorded the highest meters covered within velocity zone five and were significantly better than the TF, LF and HB for the 1st half (115.88 ± 38.42m) and 2nd half (103.99 ± 45.43m). The OB recorded the second highest meters covered within this velocity zone and were significantly better than the TF and LF. The LF and HB were both significantly better than the TF group.

Table 5.2: Results of measured metrics for primary and secondary positional groups for the 1st half and 2nd half (M±SD)

		Total distance (m)	**High speed meters (m)**	**Maximum velocity ($m.s^{-1}$)**	**Match intensity (m/min)**	**Accelerations (n)**	**Decelerations (n)**	**VZ^{3} (4.45 – 5.56 $m.s^{-1}$)**	**VZ^{4} (5.57 – 6.94 $m.s^{-1}$)**	**VZ^{5} Sprinting (>6.95 $m.s^{-1}$)**
Forwards	1st half	3089.0 ± 560.4	82.6 ± 29.2	6.62 ± 0.91	69.7 ± 8.0	384.5 ± 121.6	380.8 ± 106.3	211.9± 46.4	70.0± 24.1	12.6± 11.8
	2nd half	2645.4 ± 826.9	75.5 ± 32.4	6.58 ± 0.98	67.5 ± 10.9	343.2 ± 142.8	336.3 ± 129.2	182.9± 49.5	60.3± 24.8	15.3± 13.6
Backs	1st half	3313.8 ± 602.5	237.6 ± 53.1^	7.944 ± 1.087^	73.7 ± 11.7	382.80 ± 105.5	378.6 ± 85.4	328.8± 61.4^	166.1± 38.2^	71.7± 28.3^
	2nd half	2947.8 ± 887.7	221.6 ± 64.6^	7.786 ± 0.915^	72.0 ± 11.2	353.03 ± 123.2	344.9 ± 107.4	281.7± 69.3^	150.4± 42.9^	71.2± 33.3^
Tight Forwards	1st half	2941.4 ± 651.3	39.9 ± 22.3	6.152 ± 1.059	68.1 ± 8.7	370.9 ± 128.7	367.4 ± 112.2	138.4 ± 40.8	35.7 ± 18.4	4.2 ± 8.3
	2nd half	2411.6 ± 945.9	29.8 ± 22.1	5.979 ± 1.099	65.4 ± 12.1	313.5 ± 155.9	309.3 ± 142.5	121.6 ± 46.6	25.5 ± 18.1	4.3 ± 7.3
Loose Forwards	1st half	3236.7 ± 469.5	125.2 ± 36.1	7.087 ± 0.763^{a}	71.2 ± 7.3	398.1 ± 114.5	394.1 ± 100.4	285.4 ± 52.0^{a}	104.2 ± 29.7^{a}	21.0 ± 15.2^{a}
	2nd half	2879.3 ± 707.9	121.2 ± 42.7	7.171 ± 0.855^{a}	69.5 ± 9.8	372.8 ± 129.7	363.3 ± 115.8	244.1 ± 52.4^{a}	95.0 ± 31.4^{a}	26.2 ± 19.8^{a}
Half Backs	1st half	3566.9 ± 559.4^{a}	179.1 ± 44.4^{a}	7.426 ± 0.933^{a}	78.7 ± 10.9^{ae}	396.0 ± 104.2	392.1 ± 85.7	412.2 ± 84.4^{abde}	150.5 ± 39.3^{a}	28.6 ± 17.3^{a}
	2nd half	3053.9 ± 1009.3^{a}	170.2 ± 64.6^{a}	7.132 ± 0.799^{a}	76.6 ± 12.2^{ae}	336.0 ± 126.8	333.6 ± 111.9	348.4 ± 93.0^{abde}	140.8 ± 53.4^{a}	29.4 ± 19.8^{a}
Inside Backs	1st half	3220.8 ± 694.1	234.7 ± 53.9^{abc}	7.904 ± 0.911^{ab}	72.2 ± 13.0	376.6± 110.3	372.2 ± 89.8	312.7 ± 56.9^{a}	164.1 ± 38.0^{a}	70.6 ± 29.2^{ab}
	2nd half	2863.8 ± 864.2	237.2 ± 57.7^{abc}	7.955 ± 0.880^{abc}	70.3 ± 9.7	350.0 ± 122.2	340.8 ± 107.4	261.2 ± 58.1^{a}	157.0 ± 37.2^{ab}	80.2 ± 34.5^{ab}
Outside Backs	1st half	3153.8 ± 55.9	298.9 ± 60.8^{abcd}	8.501 ± 1.417^{abc}	70.2 ± 11.2	375.8 ± 101.9	371.6 ± 80.7	261.5 ± 42.9^{a}	183.1 ± 37.3^{ab}	115.9 ± 38.4^{abc}
	2nd half	2925.7 ± 789.5	257.5 ± 71.5^{abc}	8.270 ± 1.066^{abc}	69.2 ± 11.6	373.1 ± 120.5	360.2 ± 102.9	235.5 ± 56.8^{a}	153.5 ± 38.3^{ab}	104.0 ± 45.4^{abc}

Note: ^denotes significant differences between primary positional groupings for 1st and 2nd half. ^{a}denotes significant differences when compared with the tight forward positional group for 1st and 2nd half. ^{b}denotes significant differences when compared with the loose forward positional group for 1st and 2nd half. ^{c}denotes significant differences when compared with the half back positional group for 1st and 2nd half. ^{d}denotes significant differences when compared with the inside back positional group for 1st and 2nd half. ^{e}denotes significant differences when compared with the outside back positional group for 1st and 2nd half. VZ 3,4,5 refers to velocity zones three, four and five of the measured metrics. Statistical significance ($p \leq 0.05$)

5.4 Discussion

The aim of this study was to determine differences in in-match running demands of the primary and secondary positional groups between the 1st and 2nd halves of matches during the 2018 Varsity Cup rugby competition. Vahed *et al*. (3) found that rugby as a game has become more physical and that player actions have increased, leading to a more continuous game. According to Vahed *et al*. (3), the continuous evolving nature of the game could lead to large declines in running demands from the 1st to 2nd half, which may affect team performance. The current study found that both primary and secondary positional groups recorded the highest data in the 1st half, which is in agreement with the literature (18-20). Reasoning behind the differences could be attributed to player fatigue during the match (22), the exclusion of players substituted onto the field that did not meet the required inclusion criteria, or players who struggled to adapt to the initial demands when joining the game. Differences between primary and secondary positional groups may be because of forwards being heavier and taller than backs, which may have reduced the forwards ability to reach and maintain the same velocities over the course of each half. No evidence was found in published literature or in the reported results that the powerplay law affected the recorded data when distances were compared to relevant literature.

The major findings of this study revealed that the backs recorded higher TD, HSM, maximum velocity, match intensity and covered more distance within the three recorded velocity zones for the 1st and 2nd halves. Limited literature has been found on the differences of player demands within positional groups for the 1st and 2nd halves, making confident comparisons difficult and illustrates the need for further research.

The HB covered the most distance within velocity zone three for both halves. The OB covered the most distance for velocity zones four and five in the 1st and 2nd halves. The TF covered the least distance within the three velocity zones across the different periods measured. Results illustrates the running intensities of the back subgroups during the 1st and 2nd halves of play. The differences between the secondary positional groups showed that differences were present and the need for further research into the demands of separate groups. There is limited published literature on in-match positional running demands of South African university rugby players.

The experimental scoring law of the VC encourage teams to run from their own half of the field in pursuit of 9-point try’s rather than the standard scoring. Future studies of the VC competition may direct attention to the ball in play time over each half to try and isolate whether the law changes have increased the match intensities during ball in play time. These law changes can be seen as a possible reason for increased time spent at higher velocities. Because of the positional demands on the HB, with constant involvement in play, the HB recorded the highest TD within velocity zone three for both the 1st and 2nd halves. This is possibly because of the scrum half normally being present to clean from the base of rucks and the flyhalf generally taking up the role of the first receiver in open play. Physically, the HB group were the lightest and shortest on average of the recorded players, which may have resulted in the positional groups ability to run at the specified intensities for longer. Reardon, Tobin and Delahunt (18) report that scrumhalves and fly halves recorded distances of 543.38 ± 232.80m and 571.41 ± 102.49m, which is less than the HB group in the current study. Reardon *et al*. (18) did, however, report on all meters covered (>5.0 m. s^{-1}), which were lower velocities than reported on in the current study. Cahill *et al*. (9) reported that scrumhalves registering 887 ± 607m, which is higher than the reported meters in the current study, which could be attributed to the groupings of positions because scrumhalves were identified as individual positions. As mentioned by Cahill *et al*. (9), Owen *et al*. (6) and Tee, Lambert and Coopoo (11), scrumhalf and fly half (HB) positions are constantly involved in set and phase play, often as the link between the forwards and backs providing context to the roles of the position.

The reference articles used in the current study to make inferences about recorded data show a limited amount of both the 1st and 2nd half match data because most references focus on full match characteristics. Reported literature also does not always divide participants into positional groups and may report on individual positions. Substitutions, injuries and foul play within matches result in difficulty to accurately report on positional group demands.

Total distance

McLellan *et al.* (2011) report results of 2685 ± 641m and 3.136 ± 541m for forwards and backs over the 1st half of rugby league matches. Second half results reported were 2553 ± 558m and 2941 ± 618m for forwards and backs respectively. Although a different population, the current study recorded results for forwards and backs that were better than that of McLellan *et al.* (2011) for the 1st and 2nd half. The differences in the TD covered between both halves were, however, smaller in the McLellan *et al.* (7) study than in the current study.

Highspeed meters

There is limited available literature on high-speed meters covered for primary positional groups. The higher scores reported by Reardon *et al*. (18) could have been possible because the participants were elite rugby players. Possible reasons for the large differences could the inability of the TF to reach the minimum speed to register high-speed meters and the number of contact events involving in the TF. The results reported are similar to those reported by Reardon *et al*. (18), where the OB recorded the highest (628.4 ± 215.3m) and the TF the lowest (333.6m) scores. Jones *et al*. (2015), however, noted that the IB covered the most meters at high-speed (587 ± 205m) and the TF covered the least meters (146 ± 89m). Both studies indicate that they made use of professional players for their data collection. However, player levels, competition laws and coaching tactics may have produced lower data scores from what has been researched. In the study by Reardon *et al*. (2015), the teams might have played a more running oriented game that allowed the forwards to register more meters covered, but still have the OB covering more meters at high speeds. Jones *et al*. (2015) possibly recorded teams where the tactic was to use the IB group to control the attacks through the middle of the field. Line breaks and higher numbers of phases could have contributed to the high number of meters by the IB.

Maximum velocity

In the current study backs achieved higher velocities than forwards over both halves indicating similar results as McLellan *et al.* (7) who found the same trend among rugby league players. The backs achieved 8.5 ± 0.8 $m.s^{-1}$ and 8.6 ± 0.3 $m.s^{-1}$ for the 1st and 2nd half and the forwards 6.8 ± 0.7$m.s^{-1}$ and 6.7 ± 0.3 $m.s^{-1}$. Interestingly, primary positional groups registered their maximum velocities in the 1st half of play rather than the 2nd as indicated in the McLellan *et al.* (7) study. Tee and Coopoo (16) report similar findings where backs achieved speeds of 8.8 ± 1.1 $m.s^{-1}$ and forwards 7.6 ± 1.3 $m.s^{-1}$. The OB recorded the highest maximum velocity, following the trend in reported research (9, 16). The TF recorded the lowest maximum velocity similarly to the results of Tee and Coopoo (16) and Cahill *et al*. (9)

Match intensity

Limited published research has identified and reported on different positional groups, as well on the separate halves regarding the match intensity metric. Sirotic *et al.* (19) assessed the match intensity of national rugby league players and reported values of 108.9 ± 10.6 and 103.6 ± 10.8 m/min of play for 1st and 2nd half. Contrary to the current study, Tee and Coopoo (16) reported that forwards (70 ± 7) achieved a higher match intensity than backs (69 ± 9), which might be because of the reduced match intensities of the IB and OB secondary groups. The HB recorded the highest match intensity, which is in accordance with the findings of Tee and Coopoo (16). There results showed significantly higher match intensities than the other positional groups. The IB and OB groups recorded the lowest

Number of accelerations and decelerations

Backs completed more accelerations and decelerations than forwards, however, the differences were insignificant. Owen *et al*. (6) reported similar findings. Interestingly, in the current study the LF performed the most accelerations and decelerations in both the 1st and 2nd halves of match-play. These findings contradict the results found by Owen *et al.* (6), who found that the IB group attained the most accelerations and deceleration over the 1st half. This may be because Owen *et al.* (6) recorded only one half of the match and grouped the flyhalf position within the IB group.

Velocity zones three, four and five

Forwards covered significantly less TD within all three-velocity zones during the 1st and 2nd halves when compared to backs. The TF covered the least distance in all velocity zones in the 1st and 2nd halves, which is consistent with the literature (16, 20, 21). However, in the study by Roberts *et al*. (20) only trivial differences were found between forwards and backs.

The OB covered the most distance within velocity zone four for the 1st half and velocity zone five for the 1st and 2nd half. This is in agreement with Roberts *et al*. (20) who reported similar figures for high-speed running (456 ±185m) and sprinting (280 ±185m) for professional rugby players. This could be attributed to the nature of the positional group and the modern game where the OB players are afforded more space to run (13), along with the physical stature of the playing position allowing players to reach and maintain higher speeds, because they are lighter than forwards (1, 5). Interestingly, the TF recorded more meters in the 2nd half within velocity zone five, which could be attributed to substitutions making an impact because the players were not fatigued. Forwards and the forward subgroups were significantly heavier and taller than the backs and their subgroups in the current study (Table 5.1), which could be a possible reason for forwards having achieved lower results when compared with other secondary positional groups and over all recorded metrics.

Increases in recorded metrics from the 1st to 2nd half, may be attributed to various external factors, such as the score line (23), where teams may be trailing in points by a small margin against an opponent, type of match being played such as a final (12), tactical substitutions by coaching staff and the impact of substitutions made (12, 23), although this did not occur within this study. Literature has addressed some demands placed on players of varying positions; however, few have considered the differences and demands between each half of play. Each half of play presents different demands because players fatigue, new and fresh players are substituted onto the field, which could possibly accelerate play for the period of time that they are on the field. Strength and conditioning coaches could aim to focus efforts to understand not only the demands of each half of play, but the abilities of players based on recorded data during both halves. This allows for tactical preparation of players to meet or exceed the necessary demands of the half.

Practical application

Practical applications for each positional group are presented in Table 5.3. Recommendations on types of training for optimal conditioning, based on the recorded in-match running demands, are also presented.

Table 5.3: Practical applications and recommendations based on in match running demands for 1st and 2nd half

Positional groups	Application
Forwards	Increases in running performances within the velocity zones may be an optimal strategy to expose players to high speed running for longer bouts. Repeat speed integrated with variations in rest patterns may assist with the rate at which players running performance declines from 1st to 2nd half. Forwards complete the most contacts during a match and should prepare accordingly with exercises such as wrestling and strongman style training.
Backs	Maintaining exposure to high velocity running, reaching maximal velocity and training within higher velocity thresholds could assist in prevention detraining of players.
Tight forwards	Increase running within velocity zones and exposure to bouts of high intensity and high speed running to improve overall speed and fitness in order to improve the rate of fatigue the players face.
Loose forwards	Training programs consisting of repeated sprints, accelerations and decelerations, along with the running patterns mentioned for TF, could assist in the maintained exposure to accelerating and braking forces player encounter in-match.
Half backs	Continuous high intensity running, high TD and high continuous movements simulating the involvement of the position in-match. Repeat speed and maximal aerobic speed running would add specific overload to the running demand of the players.
Inside backs	Training may consist of high intensity running coupled with bouts of high speed running such as tempo or fartlek running to simulate the not only moving nature of the position, but the ability to move at high velocities as well for short periods of match play.
Outside backs	Maximum velocity running, high speed running coupled with periods of low intensity movement through sprints and rest periods. Specific rest periods in the form of work to rest ratios could be established to simulate exposure to both the high speed achieved as well as the periods of low intensity movement between bouts of high speed.

5.5 Conclusion

The current study aimed to determine if there were differences in in-match running demands of university rugby players for primary and secondary positional groups in the 1st and 2nd halves of match-play. It can be concluded that there were differences between the primary and secondary positional groups for the 1st and 2nd halves of match play. The backs recorded better results than the forwards in all recorded metrics over both halves of play, where results were higher in the 1st half of play and declined during the 2nd. The HB, IB and OB groups also performed better than the TF and LF groups over both halves and for all metrics. However, the LF group recorded the highest number of accelerations and decelerations. A metric that was excluded from the current study was that of impact data that should be considered for future studies regarding university population. Future research could be aimed at identifying and improving work to rest ratios, game pacing and assessing the rate of fatigue that players experience over the 1st and 2nd halves of match-play.

Limitations of the study were as follows: Small sample size was a consequence of recording only one season of competition, making use of only two teams and strict inclusion and exclusion criteria. GPS software versions and the differences in manufacturers to enable confident comparisons with previous literature. Impact data was not recorded, where this data may have affected the accelerations and decelerations of players. The lack of consistent velocity thresholds in reported literature made comparing results difficult.

Future studies should be aimed at possible pacing strategies within each half of play, noting the effect of substitutions on running demands and match play. Work to rest ratios during the 1st and 2nd halves of play, as well as the possible changes and differences in running demands because of the experimental laws on match intensity for ball in play time. Lastly, studies should focus on the anthropometrical changes experienced by university players, specifically because of the match demands of the VC. Such studies could beneficial for strength and conditioning coaches to structure specific overload into training sessions based off the match demands.

Disclosure statement

The authors reported no potential conflict of interest.

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CHAPTER SIX

SUMMARY, CONCLUSION, LIMITATIONS AND FUTURE RESEARCH

This chapter is presented herewith in accordance with the referencing style of the Department Sport Science, Stellenbosch University.

SUMMARY

Rugby union (rugby) as a popular sporting code has been subject to a variety of scientific studies across several playing levels and ages. There is a plethora of well-documented studies highlighting the physical and psychological demands of the sport. Limited literature, however, has focused on the emerging population of university student athletes and rugby players in South Africa. This population is unique in the sense that they have to cope, among others, with a full-time academic program and sporting commitments. There is scope for research relating to this population within the South African context. The purpose of the current study was to investigate positional specific running demands of South African rugby at university level during match-play.

The first research question posed related to differences in in-match running demands between positional groups in South African university rugby players, this question directed the first aim. The first aim (research article one) of the study was to investigate the in-match running demands of South African university rugby players by using GPS during match play for primary and secondary positional groups.

Two further research questions were posed to identify the second aim (research article two) of the study: i) are there differences in the in-match running demands between the 1st and 2nd halves during the Varsity Cup competition?; and, ii) are there differences in the in-match running demands of the primary and secondary positional groups between the 1st and 2nd halves of matches during the Varsity Cup rugby competition?

The current thesis is presented in six main parts, namely an introduction (Chapter One), literature review (Chapter Two), methodology (Chapter Three), research article one (Chapter Four), research article two (Chapter Five) and the conclusion (Chapter Six). The Senate of Stellenbosch University approved the article format and the two research articles were presented in accordance with the guidelines outlined by the respective journals. Currently, the Faculty of Medicine and Health Sciences at Stellenbosch University stipulates one article as requirement for the article format. Chapter One introduced the problem and stated the primary aim and the specific study objectives of the study.

Chapter Two (literature review) described the various aspects of the game of rugby and current research conducted in the field of Sport Science focusing on player movement tracking. The chapter gave an overview of the use of global positioning systems (GPS) and its effectiveness in player movement tracking in both rugby and other team sport, as well as some individual examples. The chapter further elaborates on the different metrics tracked and the impact of tracking players for those metrics using time motion analysis processes, specifically GPS. The chapter highlights the effectiveness of current research on player movement tracking for both training and match purposes allowing coaching staff to achieve superior player performance.

Chapter Three introduced the methodology. This chapter explains the methods, materials and participants used for the study. Detailed descriptions of the processes followed to select participants, collect and extract data and report on collected data were disclosed. A description of the ethical aspect and the ethical clearance number is also included herein.

Research article one is titled*: In-match differences in running demands of South African university rugby players*.

Results showed that of the primary positional groups, the backs were involved in more total distance, high speed meters and meters within the velocity zones than the forwards and both differences and significant differences were found for the recorded variables. Secondary positional groups showed significant differences between the forward and back subgroupings, where the HB recorded the highest TD (significantly more than all secondary positional groups), match intensity (significantly higher than the TF and OB), and distance within velocity zone three (significantly more than all the secondary positional groups). The OB recorded the most HSM (significantly more than all the secondary positional groups), the highest maximum velocity (significantly higher than the TF, LF and HB), and the most meters within velocity zone four (significantly more than the TF and LF), and velocity zone five (significantly more than the TF, LF and HB). The findings of the current study indicate the running demands of playing in the Varsity Cup tournament for various positional groups, which provide insight into the in-match demands that player's experience. The practical implications of structuring training sessions around match demands can assist coaches, strength and conditioning coaches in player management and optimizing training stimuli to cater for the demands of competition.

Chapter Five contains research article two. The article is titled: *Positional differences in in-match running demands between the 1st and 2nd halves of the 2018 Varsity Cup rugby competition*. Results described differences between primary positional groups for all the measured metrics between the 1st and 2nd halves, where backs recorded more or higher than the forwards for each half. Recorded metrics experienced a decline from the 1st to the 2nd half for both primary and secondary positional groups. Significant differences were found for HSM, maximum velocity and distance covered in the three velocity zones for both the 1st and 2nd half. The secondary positional groups identified differences among all metrics recorded for the 1st and 2nd half. The HB recorded the most TD (1st and 2nd half), match intensity (1st and 2nd half) and distance within velocity zone three (1st and 2nd half). The OB recorded the most HSM, highest maximum velocity and the most distance within velocity zones four and five for the 1st and 2nd half. Interestingly, the LF completed the most accelerations and decelerations for the 1st and 2nd half.

In summary, there is limited literature and published research on the running demands of university rugby players, during both training and match play. It could be inferred that teams' data may be utilized to adapt training programs to fit the demands of the varsity cup competition. Additionally, coaching staff making use of numerous forms of time motion analysis, such as match coding and video recordings may be able to further assess player effectiveness during their on-field performances.

CONCLUSION

The conclusions derived from this study were presented according to the specific objectives and hypothesis set in Chapter One.

Research article One: In-match differences in running demands of South African university rugby players.

Major findings of this study include the ranges of differences found between positional groups for the full match. Backline players covered greater total distance, showed higher match intensity, as well as maximum speed and high-speed meter coverage compared to the forwards. Following research (Cunniffe *et al*., 2009; Cahill *et al*, 2013; Cummins *et al*., 2013; Reardon *et al*., 2015; Read *et al*., 2018), contrary to some reported research (Quarrie *et al*., 2013), where the OB recorded the highest total distance, the HB group attained the greatest total distances in the full match. The HB group also recorded the highest match intensity, which can be an indication of the constant involvement of these positions during match-play. The OB achieved the greatest maximum velocity and recorded the highest amount of high-speed meters covered, which is in agreement with reported literature (Roberts *et al*., 2008; Austin *et al*., 2011). Tight forwards recorded the lowest totals of all metrics, which is also in agreement with literature (McLellan *et al*., 2011; Quarrie *et al*., 2013; Austin & Kelly, 2014; Reardon *et al*, 2015). Half backs recorded the most distance covered within velocity zone three. Similar findings have been reported for the scrum half position as positional groupings vary within literature (Cahill *et al*., 2013; Reardon *et al*., 2015). This could be attributed to the constant involvement as the first receiver and link between the forwards and backs. A variable that may have influenced the increases in running performances was the laws of the Varsity Cup tournament fostering more running rugby by creating a try scoring culture (Kraak *et al*., 2017). Outside backs recorded the most distance covered for velocity zones four and five, which is in agreement with other studies (Roberts *et al*., 2008; Cummins *et al*., 2013; Owen *et al*., 2015). Tight forwards covered the least distance of all positional groups for all the velocity zones and periods, which is in correspondence with literature. The positional involvement in physical contact and ball contention requires that these players are typically larger and heavier than the backs (Lombard *et al*., 2015; Owen *et al*., 2015).

Result from the current study show that, similar to previous research, differences in running demands were identified between primary and secondary positional groups. Previous studies do not differ significantly in terms of differences between primary and secondary positional groups for recorded data (Roberts *et al*., 2008; Cahill *et al*., 2013; Quarrie *et al*., 2013; Reardon *et al*., 2015).

The article provides data on in-match differences in running demands of university rugby players and can be seen as a foundation for future studies and possibly the formation of norms and standards that teams may base training session demands on. Importantly, if the current rules of the VC competition cause more running during matches, strength and conditioning coaches should not rely only on published match results from typical matches, conducted under different laws.

Hypotheses:

H_1: The in match running demands of forwards will be significantly less than the total distance covered, total high-speed meters, maximum velocity, match intensity, number of accelerations and declarations and the total distance covered in each velocity zone than the backs for the duration of match-play.

H_o: The in match running demands of forwards will not be significantly less than the total distance covered, total high-speed meters, maximum velocity, match intensity, number of accelerations and declarations and the total distance covered in each velocity zone than the backs for the duration of match-play the backs for the duration of match-play.

Rejected: The forwards did cover significantly less total distance, total high-speed meters, maximum velocity, match intensity, number of accelerations and declarations and the total distance covered in each velocity zone than the backs, however, not for all metrics measured.

H_1: The total distance covered, total high-speed meters, maximum velocity, match intensity, number of accelerations and declarations and the total distance covered in each velocity zone of secondary positional groups will be significantly more for the half, inside and outside back groups than the tight and loose forward groups for the duration of match play.

H_o: The total distance covered, total high-speed meters, maximum velocity, match intensity, number of accelerations and declarations and the total distance covered in each velocity zone of secondary positional groups will not be significantly more for the half backs, inside backs and outside back groups than the tight and loose forward groups for the duration of match-play.

Rejected: The total distance covered, total high-speed meters, maximum velocity, match intensity, and the total distance covered in each velocity zone of secondary positional groups was significantly more for the half backs, inside backs and outside back groups than the tight and loose forward groups, however the number of accelerations and decelerations was not.

Research article Two: Positional differences in in-match running demands between the 1st and 2nd halves of the 2018 Varsity Cup rugby competition.

Major findings within the current study indicated that there are positional differences in in-match running demands between the 1st and 2nd halves of match-play for primary and secondary positional groups. Differences were observed between the primary positional groups, where backs recorded more and higher results for all measured metrics for both the 1st and 2nd halves. Significant differences were observed when comparing backs to forwards for HSM (higher for the 1st and 2nd half), maximum velocity (higher for the 1st and 2nd half), and velocity zones three, four and five (higher for the 1st and 2nd half). The findings of the primary positional groups agree with the reported studies of Cunniffe *et al*. (2009), Cahill *et al*. (2013), Cummins *et al*. (2013), Owen *et al.* (2015), Reardon *et al*. (2015) and Read *et al*. (2018) however, there may be some discrepancies as the duration of these studies varies and is inconsistent for comparison.

Secondary positional groups similarly displayed differences between metrics over the 1st and 2nd halves. The HB recorded the highest TD (significantly better than the TF), match intensity (significantly better than the TF and OB), and cover the most distance within velocity zone three (significantly better than the TF, LF, IB and OB) for the 1st and 2nd halves. The OB recorded the most HSM (significantly better than the TF, LF, HB and IB), highest maximum velocity (significantly better than the TF, LF and HB), and the most distance within velocity zone four (significantly better than the TF and LF) and five (significantly better than the TF, LF and HB) for the 1st and 2nd halves. The OB results agree with the study of Roberts *et al.* (2008) and Austin *et al.* (2015). The LF recorded the most accelerations and decelerations for both the 1st and 2nd halves of match-play, which is contrary to reports by Owen *et al.* (2015), who reported that inside backs recorded the most. Sample size, duration and positional groupings may have influenced the result of Owen *et al.* (2015) study. Limited published research on the recorded metrics of the current study over the 1st and 2nd halves have been reported. This makes it difficult to make confident inferences and comparisons about results because the duration of reported studies is over the full match or a single half. Results show similar trends to what has been reported in full match analysis, however, no known reports on individual halves have been recorded.

Differences between positional groups over the 1st and 2nd halves may lead strength and conditioning coaches to attempt new approaches in training to enhance performance through the implementation of match specific pacing strategies that combat the rate of player fatigue. Overall, all positional groups experience declines in running demands from the 1st to 2nd half of play. Strength and conditioning coaches should remain focused on improving the general conditioning for teams, however, integrate exercises specific to match demands, such as high speed running for outside backs and more exposure to high speed running for tight forwards.

University-specific competitions remain largely understudied in the Sport Science field. The current study could contribute to interest for research and deeper analysis of this specific format of play.

Hypotheses:

H_1: Significant differences between primary positional groups will be found with regards to total distance covered, total high-speed meters, maximum velocity, match intensity, number of accelerations and declarations and the total distance covered in each velocity zone for the 1^{st} and 2^{nd} halves.

H_o: Significant differences between primary positional groups will not be found with regards to total distance covered, total high-speed meters, maximum velocity, match intensity, number of accelerations and declarations and the total distance covered in each velocity zone for the 1^{st} and 2^{nd} halves.

Rejected: Significant differences were only found in high speeds meters, maximum velocity and the distances covered within each velocity zone for the 1^{st} and 2^{nd} halves for the primary positional group.

$H_{1:}$ Significant differences between secondary positional groups will be found regarding total distance covered, total high-speed meters, maximum velocity, match intensity, number of accelerations and declarations and the total distance covered in each velocity zone for the 1^{st} and 2^{nd} halves.

H_o: Significant differences between secondary positional groups will not be found regarding to total distance covered, total high-speed meters, maximum velocity, match intensity, number of accelerations and declarations and the total distance covered in each velocity zone for the 1^{st} and 2^{nd} halves.

Rejected: Significant differences were found in the secondary positional groups for all recorded metrics except the number of accelerations and decelerations, which presented only differences.

LIMITATIONS

- Small sample size due to, GPS malfunction, players and teams not meeting the GPS or minimum time requirements and only recording two teams over one competitive season.
- Lack of normative values for velocity thresholds.
- Lack of normative values for velocity thresholds for both primary and secondary positional groups, as well as the use of absolute thresholds over individualised thresholds.
- Tactical substitutions of players further reducing sample size.
- No consistent data on valid inclusion times for player data.
- No contact data was recorded, which may have impacted the results seen for some metrics.

FUTURE RESEARCH

- Future research should target establishing individualized velocity zones for positional groups; however, it must consider the possible changes in positional playing demands because of changing tactics by coaches because positional demand groupings may change. This may aid in research done on a more robust positional grouping system that provides effective data on positional groups rather than individual which positions, which can be time consuming.
- Intervention studies attempting to establish training modalities that best target match velocity demands. Player's responses, team success and possible injury risks associated with training at match intensities.
- Identifying the optimal time frame for inclusion criteria as different coaching staff may choose to make substitutions at different times, resulting in sample size changes.
- Increased sample size of universities over several seasons to assess successful and unsuccessful teams and the running demand profiles they generate.
- Studies that find an agreement for the velocity zones of rugby players and more specifically the running performances of different positional groups.

- Studies integrating coaches, assessing player effectiveness using multiple forms of time motion and match analysis. Profiling and establishing standards for positions based on both quantitative and qualitative data.
- The integration of impact data and its effect on running demands and the possible rate of fatigue associated with impacts.
- Effect of work to rest ratios for university players and the effects of substitutions on playing results.
- Pacing strategies in this adapted format of the game.

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APPENDIX A: CONSENT FORM

INFORMED CONSENT FORM

Research title: Time Motion Analysis of Varsity Cup Rugby using GPS Technology

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

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

Contact details of researchers:

Primary investigator

Prof Derik Coetzee (University of the Free State)

Tel: 051 401 2944

Email: coetzeef@ufs.ac.za

Co-investigators

Dr Wilbur Kraak (Stellenbosch University)

Tel: 021 808 2379

Email: kjw@sun.ac.za

Kobus Calldo (MSc student – University of the Free State)

Tel: 060 5875 991

Email: CalldoJG@ufs.ac.za

Cameron Donkin (MSc student – Stellenbosch University)

Tel: 0834062667

Email: 18251196@sun.ac.za

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

There is no payment for your involvement in this study and no "out of pocket" expenses will be expected of you.

Your participation in this research is voluntary, and you will not be penalised or lose benefits if you refuse to participate or decide to terminate participation.

Freedom of consent

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

____

Name and surname

____

ID Number

______________________ ______________________

Signature of Participant Date

______________________ ______________________

Signature of Witness Date

APPENDIX B: ETHICAL APPROVAL LETTER

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

UFS·UV
HEALTH SCIENCES
GESONDHEIDSWETENSKAPPE

IRB nr 00006240
REC Reference nr 230408-011
IORG0005187
FWA00012784

01 March 2017

JG CALLDO
DEPT OF EXERCISE AND SPORT SCIENCES
FACULTY OF HEALTH SCENCES
UFS

Dear JG Calldo

HSREC 03/2017 (UFS-HSD2017/0062)
PROJECT TITLE: TIME MOTION ANALYSIS OF VARSITY CUP RUGBY USING GPS TECHNOLOGY

1. You are hereby kindly informed that, at the meeting held on 28 February 2017, the Health Sciences Research Ethics Committee (HSREC) approved this protocol after all conditions were met.

2. The Committee must be informed of any serious adverse event and/or termination of the study.

3. Any amendment, extension or other modifications to the protocol must be submitted to the HSREC for approval.

4. A progress report should be submitted within one year of approval and annually for long term studies.

5. A final report should be submitted at the completion of the study.

6. Kindly use the **HSREC NR** as reference in correspondence to the HSREC Secretariat.

7. The HSREC functions in compliance with, but not limited to, the following documents and guidelines: The SA National Health Act. No. 61 of 2003; Ethics in Health Research: Principles, Structures and Processes (2015); SA GCP(2006); Declaration of Helsinki; The Belmont Report; The US Office of Human Research Protections 45 CFR 461 (for non-exempt research with human participants conducted or supported by the US Department of Health and Human Services- (HHS), 21 CFR 50, 21 CFR 56; CIOMS; ICH-GCP-E6 Sections 1-4; The International Conference on Harmonization and Technical Requirements for Registration of Pharmaceuticals for Human Use (ICH Tripartite), Guidelines of the SA Medicines Control Council as well as Laws and Regulations with regard to the Control of Medicines, Constitution of the HSREC of the Faculty of Health Sciences.

Yours faithfully

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

Health Sciences Research Ethics Committee
Office of the Dean: Health Sciences
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APPENDIX C: INSTRUCTIONS TO AUTHORS: JOURNAL OF SPORT SCIENCE

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Please note that this journal only publishes manuscripts in English.

Journal of Sports Sciences accepts the following types of article: Original Articles, Case Studies, Letters to the Editor, Systematic Reviews and Meta-analysis.

The Journal of Sports Sciences is published on behalf of the British Association of Sport and Exercise Sciences, in association with the International Society for Advancement of Kinanthropometry. The emphasis is on the human sciences applied to sport and exercise. Topics covered also include technologies such as design of sports equipment, research into training, and modelling and predicting performance; papers evaluating (rather than simply presenting) new methods or procedures will also be considered.

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Your paper should be compiled in the following order: title page; abstract; keywords; main text introduction, materials and methods, results, discussion; acknowledgments; declaration of interest statement; references; appendices (as appropriate); table(s) with caption(s) (on individual pages); figures; figure captions (as a list).

Word Limits

Please include a word count for your paper.

A typical paper for this journal should be approximately 4000 words, this is a guideline and not a limit; this guideline does not include tables, references, figure captions.

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APPENDIX D: INSTRUCTIONS TO AUTHORS: JOURNAL OF STRENGTH AND CONDITIONING RESEARCH

The Journal of Strength and Conditioning Research (JSCR) is the official research journal of the National Strength and Conditioning Association (NSCA). The JSCR is published monthly. Membership in the NSCA is not a requirement for publication in the journal. JSCR publishes original investigations, reviews, symposia, research notes, and technical and methodological reports contributing to the knowledge about strength and conditioning in sport and exercise. All manuscripts must be original works and present practical applications to the strength and conditioning professional or provide the basis for further applied research in the area. Manuscripts are subjected to a "double blind" peer review by at least two reviewers selected by Senior Associate Editors who are experts in the field. In some cases a "single blind" peer review may occur if a Senior Associate Editor is forced to serve as a reviewer. All editorial decisions are final and will be based on the quality, clarity, style, rank, and importance of the submission relative to the goals and objectives of the NSCA and the journal. Manuscripts can be rejected on impact alone as it relates to how the findings impact evidence based practice for strength and conditioning professionals, end users, and clinicians. Thus, it is important authors realize this when submitting manuscripts to the journal.

JSCR Senior Associate Editors will administratively REJECT a paper before review if it is deemed to have very low impact on practice, out of scope of the journal, poor experimental design, improperly formatted, and/or poorly written. Additionally, upon any revision the manuscript can be REJECTED if experimental issues and impact are not adequately addressed to reviewers, Senior Associate Editor, or Editor-in-Chief's satisfaction. The formatting of the manuscript is of great importance and manuscripts will be rejected if NOT PROPERLY formatted.

EDITORIAL MISSION STATEMENT

The editorial mission of the JSCR, formerly the Journal of Applied Sport Science Research (JASSR), is to advance the knowledge about strength and conditioning through research. Since 1978 the NSCA has attempted to ‘‘bridge the gap’’ from the scientific laboratory to the field practitioner. A unique aspect of this journal is the inclusion of recommendations for the practical use of research findings. While the journal name identifies strength and conditioning as separate entities, strength is considered a part of conditioning. This journal wishes to promote the publication of peer-reviewed manuscripts that add to our understanding of strength training and conditioning for fitness and sport through applied exercise and sport science. The conditioning process and proper exercise prescription impact a wide range of populations from children to older adults, from youth sport to professional athletes. Understanding the conditioning process and how other practices such as such as nutrition, technology, exercise techniques, and biomechanics support it is important for the practitioner to know.

Original Research

JSCR publishes research on the effects of training programs on physical performance and function to the underlying biological basis for exercise performance as well as research from a number of disciplines attempting to gain insights about sport, sport demands, sport profiles, conditioning, and exercise such as biomechanics, exercise physiology, motor learning, nutrition, and psychology. A primary goal of JSCR is to provide an improved scientific basis for conditioning practices. JSCR will ONLY CONSIDER original manuscripts not currently under consideration from other journals. JSCR will NOT CONSIDER any manuscripts previously published on preprint servers or resubmitted manuscripts previously rejected by JSCR.

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JSCR publishes symposia, brief reviews, technical reports and research notes that are related to the journal's mission. A symposium is a group of articles by different authors that address an issue from various perspectives. The brief reviews should provide a critical examination of the literature and integrate the results of previous research in an attempt to educate the reader as to the basic and applied aspects of the topic. We are especially interested in applied aspects of the reviewed literature. In addition, the author(s) should have experience and research background in the topic area they are writing about in order to claim expertise in this area of study and give credibility to their recommendations. A research note is a brief research study (~1500-2000 words) that typically consists of a simple research design and only few dependent variables. It is formatted identical to an original study with the same features, i.e. Abstract, Introduction, Methods, Results, Discussion, Practical Applications, and References, but with limited tables, figures, and reference numbers.

The JSCR strongly encourages the submission of manuscripts detailing methodologies that help to advance the study and improve the practice of strength and conditioning.

Manuscript Clarifications

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The text must contain the following sections with titles in ALL CAPS (i.e. INTRODUCTION, METHODS, RESULTS, DISCUSSION, PRACTICAL APPLICATIONS, ACKNOWLDGMENTS, and REFERENCES) in this exact order:

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Book

Lohman, TG. *Advances in Body Composition Assessment*. Champaign, IL: Human Kinetics, 1992.

Chapter in an edited book

Yahara, ML. The shoulder. In: *Clinical Orthopedic Physical Therapy*. J.K. Richardson and Z.A. Iglarsh, eds. Philadelphia: Saunders, 1994. pp. 159–199.

Software

Howard, A. Moments ½software_. University of Queensland, 1992.

Proceedings

Viru, A, Viru, M, Harris, R, Oopik, V, Nurmekivi, A, Medijainen, L, Timpmann, S. Performance capacity in middle-distance runners after enrichment of diet by creatine and creatine action on protein synthesis rate. In: Proceedings of the 2nd Maccabiah-Wingate International Congress of Sport and Coaching Sciences. G. Tenenbaum and T. Raz-Liebermann, eds. Netanya, Israel, Wingate Institute, 1993. pp. 22–30.

Dissertation/Thesis

Bartholmew, SA. Plyometric and vertical jump training.Master's thesis, University of North Carolina, Chapel Hill, 1985.

6. Acknowledgments

In this section you can place the information related to identification of funding sources; current contact information of corresponding author; and gratitude to other people involved with the conduct of the experiment. In this part of the paper the conflict of interest information must be included. In particular, authors should: 1) Disclose professional relationships with companies or manufacturers who will benefit from the results of the present study, 2) Cite the specific grant support for the study and 3) State that the results of the present study do not constitute endorsement of the product by the authors or the NSCA. Failure to disclose such information could result in the rejection of the submitted manuscript.

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Selected conversion factors:

_ 1 N = 0.102 kg (force);

_ 1 J = 1 N_m = 0.000239 kcal = 0.102 kg_m;

_ 1 kJ = 1000 N_m = 0.239 kcal = 102 kg_m;

_ 1 W = 1 J_s-1 = 6.118 kg_m_min-1.

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03 December 2019

TO WHOM IT MAY CONCERN

I, Prof Karel J. van Deventer, hereby declare that I conducted the language and technical editing of an MSc Master thesis titled, *In-match running demands of South African university rugby union players using Global Positioning Systems*, authored by Mr Cameron Donkin.

Yours sincerely

KJ van Deventer

(Emeritus Associate Professor [Retired])

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