THE EFFECT OF THE LAW CHANGES ON THE PHYSICAL PROFILE OF THE SOUTH AFRICAN CURRIE CUP RUGBY TOURNAMENT DURING 2007 AND 2013

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DECLARATION

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own original work, that I am the authorship owner thereof (unless to the extent explicitly otherwise stated) and that I have not previously submitted it in its entirety or in part for obtaining any qualification.

The co-authors of the two articles that form part of this thesis, Mr Wilbur J. Kraak (supervisor) and Dr Ranel E. Venter (co-supervisor), hereby give permission for the candidate, Mr Mohammed Yusuf Vahed, to include the two articles as part of a Master's thesis. The contribution (advice and support) of the co-authors was kept within reasonable limits, thereby enabling the candidate to submit this thesis for examination purposes. This thesis therefore serves as fulfilment of the requirements for the degree Master of Science in Sport Science at Stellenbosch University.

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Mum, I did it!

SUMMARY

With the introduction of professionalism in 1995, rugby union has rapidly and continuously changed. One such change was the introduction of several law changes after the 2007 Rugby World Cup to increase the appeal, continuity and safety of the game. Research on the effects of these law changes has primarily focused on the technical and tactical aspects of the game and very little on the changes to the physical profile of match play, particularly in a South African context. The first objective of this study was to compare the 2007 and 2013 seasons of the South African Currie Cup tournament in order to determine whether there were any effects as a result of the law changes on the scoring, time interval, general skills and contact profiles. The second objective was to compare the 2007 and 2013 seasons of the South African Currie Cup tournament in order to determine the impact of the law changes on the time variables.

This thesis will follow a research article format. Research article one will address the first objective of the study. The first major finding of the study was that the profile of the game has changed to a more physical and continuous game. There was an increase in the number of player actions (passing, tackling and rucks/mauls) ($p < 0.01$), as well as significantly more penalty goals ($p < 0.01$). The results further revealed that fewer tries were scored ($p = 0.07$), while the number of stoppages to the game, scrums and line-outs also showed a decrease ($p < 0.01$). These findings, mentioned above, were more prominent in the second half of the match. A trend revealed that teams were adopting a more defensive playing style, whereby they sacrificed committing numbers to the breakdowns and rather commit players on defence. This has created a more physically intense match with fewer tries being scored.

The second research article will address the second objective of the study. Results of the study show that the profile of the game has changed to a more dynamic, continuous game with less time spent in rucks/mauls and fewer set pieces (scrums and line-outs). The duration of the match has increased owing to an increase in total stoppage time, mainly as a result of greater use being made of the TMO. This is evident in the significant increase in total match time ($p < 0.01$) and total stoppage time ($p < 0.01$), while the total ball-in-play time was significantly less ($p < 0.01$). The total tackle time has increased significantly ($p < 0.01$), while the total ruck/maul, scrum and line-out time decreased significantly ($p < 0.01$).

By analysing the match profile, as with this thesis, coaches and trainers will be better informed to develop training programmes that are specific to the demands of modern match play. Based on the results, coaches and trainers should develop individual and team performance profiles to better understand the physical demands experienced by the players and teams, which will assist in implementing more specific recovery strategies and planning of training loads. The conditioning and skills development of players should focus primarily on contact situations (tackling and rucking) by adding contact elements to agility training and skill-based drills. With the various contact times measured, trainers can determine specific durations of muscle tension needed to overload and strengthen players by adjusting the movements of an exercise. These applications will allow coaches and trainers to prepare players for the specific demands of the modern game.

OPSOMMING

Sedert die begin van professionalisme in rugby in 1995 het die spel vinnig en aanhoudend verander. Een van hierdie veranderinge was die instelling van verskeie reëlveranderings ná die 2007 Rugby Wêreldbekertoernooi om die aantreklikheid, kontinuïteit en veiligheid van die spel te verhoog. Navorsing wat die uitwerking van hierdie reëlveranderings ondersoek het, het veral gefokus op die tegniese en taktiese aspekte van die spel en baie min op die veranderinge in die fisieke profiel van wedstrydspel, veral in die Suid-Afrikaanse konteks. Die eerste doelwit van die studie was om die 2007 en 2013 seisoen van die Suid-Afrikaanse Curriebekertoernooi te vergelyk om te bepaal wat die uitwerking van die reëlveranderings op die aanteken van punte, tydsinterval, algemene vaardighede en kontakprofiele was. Die tweede doelwit was om die 2007 en 2013 seisoen van die Suid-Afrikaanse Curriebekertoernooi te vergelyk om die impak van die reëlveranderings op tydveranderlikes te bepaal.

Hierdie tesis is saamgestel volgens ‘n artikelgebaseerde formaat. Navorsingsartikel een spreek die eerste doelwit van die studie aan. Die eerste hoofbevinding van die studie was dat die spel verander het na ‘n meer fisieke, aaneenlopende tipe spel, met ‘n toename in speler-aksies (aangeë, laagvatte, losskrums en losgemale) en ‘n afname in die aantal kere wat die spel gestop het, veral in die tweede helfte. Daar was ‘n toename in die aantal speler-aksies (aangeë, laagvatte, losskrums en losgemale) ($p < 0.01$), sowel as beduidend meer strafskoppe ($p < 0.01$). Resultate het verder gewys dat minder drieë gedruk is ($p = 0.07$), terwyl die aantal kere wat die spel gestop het, en skrums en lynstane ook verminder het ($p < 0.01$). Die bevindings soos hierbo uiteengesit, was meer prominent in die tweede helfte van ‘n wedstryd. Daar was ‘n neiging dat spanne ‘n meer verdedigende speelstyl aangeneem het, waar hulle verkies het om spelers op verdedigend te plaas as om meer spelers by die afbreekpunte te hê. Dit het ‘n wedstryd geskep wat fisiek meer intens was met minder drieë wat gedruk is.

Die tweede navorsingsartikel het die tweede doelwit van die studie aangespreek. Resultate van die studie het aangedui dat die profiel van die spel verander het na ‘n meer dinamiese, aaneenlopende spel met ‘n afname in die tyd wat aan losskrums/losgemale bestee word, met minder vaste spel (skrums en lynstane). Die duur van die wedstryd het toegeneem as gevolg van ‘n toename in die totale stoptyd, veral as gevolg van die gebruik van die TMO. Dit blyk uit die beduidende toename in totale wedstrydtyd ($p < 0.01$) en totale stoptyd ($p < 0.01$), terwyl die totale tyd wat die bal in spel was, betekenisvol afgeneem het ($p < 0.01$). Die totale

laagvattyd het beduidend toegeneem ($p < 0.01$), terwyl die totale losskrum-/losgemaal-, skrum- en lynstaantyd betekenisvol afgeneem het ($p < 0.01$).

Deur die wedstrydprofiel te ontleed, kan afrigters hul oefenprogram aanpas om aan die spesifieke vereistes van wedstrydspel te voldoen. Afrigters behoort profiele van individuele en spanprestasie te ontwikkel wat op die resultate gegrond is ten einde ‘n beter begrip te verkry van die fisieke eise waaraan die spelers en spanne onderwerp word. Dit sal help met die implementering van spesieke herstelstrategieë en die beplanning van oefenladings. Die kondisionering en vaardigheidsontwikkeling van spelers behoort hoofsaaklik toegespits te word op kontaksituasies (laagvatte en losskrums) deur kontakelemente by ratsheids- en vaardigheidsoefeninge te voeg. Deur die meting van die verskillende kontaktye kan afrigters die spesifieke duur van spierspanning bepaal wat nodig is om spelers sterker te maak, en die bewegings van ‘n oefening daarvolgens aanpas. Hierdie toepassings sal afrigters in staat stel om spelers vir die bepaalde eise van die moderne spel voor te berei.

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LIST OF ABBREVIATIONS

CM	Centre of mass
CNA	Computerised notational analysis
ELVs	Experimental law variations
IRB	International Rugby Board
N	Total number of matches
n	Total number of matches per season
PA	Performance analysis
PIs	Performance indicators
SA	South Africa
SARU	South African Rugby Union
TMO	Television match official

APPENDICES

CHAPTER ONE

INTRODUCTION AND PROBLEM STATEMENT

This chapter is included herewith in accordance with the guidelines of the *International Journal of Performance Analysis in Sport* (Appendix A).

1.1 Introduction

The profile of sports rarely remains the same, as the game is frequently pushed to the limit both by the players and coaches (Eaves *et al.*, 2008*).* Players have become faster, stronger, more powerful and clinical in implementing these physical attributes within the laws of the game (Smart *et al.*, 2013; Kraak *et al.*, 2011; Austin *et al.*, 2011). In order to gain the competitive edge over opposing teams, coaches and trainers need to adapt their current training programmes to accommodate and take advantage of these changes to the profile of the game (Eaves *et al.*, 2008; Eaves & Hughes, 2003). Since rugby union became professional in 1995, the science of examining the sport and participants' performance has grown rapidly to meet the increasing demand for knowledge on game tactics and player characteristics (Duthie *et al.*, 2003). With the continued development of professional sport, the use of technology and scientific support has becoming increasingly emphasised to aid coaches and trainers in the coaching process (James *et al.*, 2005). The use of performance analysis (PA), more specifically notational analysis or match analysis services, has become increasingly accessible to rugby coaches to allow them to gain the competitive edge over the opposition as PA provides trainers and coaches with detailed analysis on individuals' and teams' performances (Wright *et al.*, 2012).

O'Donoghue (2006) stated that the primary aim of PA, in a coaching context, is to provide information about actual performances to assist coaches, trainers and players with their decision making. Video analysis is used to provide coaches with this information on performance during training and competition. Video analysis can be used to analyse technical, tactical and biomechanical aspects of the game and enhances the coach and trainer's ability to identify and diagnose problems (Wright *et al.*, 2012; O'Donoghue, 2006; Hughes & Bartlett, 2002; Bartlett, 2001). Many of the computer-based video analysis systems integrate quantitative performance with video images (O'Donoghue, 2006). These systems can be tailored to any sport using performance indicators (PIs). PIs are a selection or combination of action variables that aim to define an aspect of a performance during training and match play (Jones *et al.*, 2004; Hughes & Bartlett, 2002). The development and utilisation of PIs can subsequently lead to the creation of performance profiles which, according to Jones *et al.* (2004), can be a description of a pattern of performance by a team or an individual profile (Jones *et al.*, 2004; Hughes & Bartlett, 2002). Such profiles can lead to a better understanding of various situations and tactics implemented by teams, which offers some prediction of future performances (Robertson & Joyce, 2014; Jones *et al.*, 2004). However, little research has been

done on the construction of PIs and profiles for physical training and conditioning purposes in rugby union (Jones *et al.*, 2004).

Changes to the laws are fundamental to the development of rugby and are introduced for several reasons (Kraak & Welman, 2014; Eaves *et al.*, 2008). Williams *et al.* (2005) and Eaves *et al.* (2008) have suggested that law changes in rugby are implemented to improve safety, by reducing contact situations and the potential for players to get injured. In addition they should also increase both the competitiveness and continuity of the game, which would make the game more attractive to players and spectators. Evaluation of the effects of law changes on the match profile has primarily focused on technical and tactical aspects of the game and very little on the physical profile and its implications for the training and conditioning of players and teams (Wright *et al*., 2012; O'Donoghue, 2006; Hughes & Bartlett, 2002; Bartlett, 2001). Williams *et al.* (2005) (1999-2003) and Eaves and Hughes (2003) (1988-2002) identified the changes that occurred within the game found that the match and ball-in-play time as well as ruck frequency increased significantly. It was suggested that this was largely due to the law changes introduced over the period of the research. Furthermore, Van den Berg and Malan (2012) investigated whether the experimental law variations (ELVs), introduced in 2008, were effective in making rugby matches more appealing to spectators by improving the continuity of the games. They analysed all the Super 14 teams of the 2006 and 2008 tournaments and found the number of scrums and line-outs decreased but that the number of tackles made, metres gained and penalties conceded increased significantly. The authors concluded that the increase in player activities (passing, tackling, rucking) that promoted continuity suggested that the ELVs implemented have succeeded in enhancing the appeal of the game. These works have clearly established that the game has become more physically demanding. However, these studies fail to mention the effect of the law changes on the physical profile of the game or the training implications thereof for players or teams.

Duthie *et al.* (2003) conducted a review of the research into the physiological demands on rugby players and the use of performance analysis. The authors analysed the physical characteristics (body mass, height, muscle-fibre types) and physical capacities (maximal oxygen uptake, anaerobic performance, muscle strength and power and speed) of rugby players. They also suggested that law changes have made play "more open" and faster but that the data they collected for the review may not accurately reflect the current game due to the changes to the game's profile. Eaves and Hughes (2003) identified the changes that occurred

to the time and frequency of activity and ball recycling in international rugby matches (1998-2002). They found that players are performing activities significantly more quickly and more frequently, while total game activity has also increased. Similarly, the frequency of rucks has increased and although the speed of ball recycling has been consistent the results suggest that the game activity patterns may have shifted towards a faster ruck-dominated game with more phases of play. The authors stated that the game has become more physically demanding since the introduction of professionalism and that the law changes implemented during the period have made an impact on playing styles and strategies used by the different teams. Thus, with the changing profile of the sport, the training of players cannot remain the same and training programmes must adapt and accommodate the law changes and the effects thereof on the physical demands made on players.

It has been well established that the physical demands on the players need to be constantly monitored in order to draw up effective training programmes (Smart *et al*., 2013; Quarrie *et al*., 2013; Austin *et al*., 2011). More comprehensive research on the physical characteristics of players, fitness requirements and movement patterns of rugby needs to be done. However, there is research (albeit still limited) that indicates how coaches and trainers can implement performance analysis in their training programmes. It has been made clear that there is a "gap" between research and coaching practice, especially within the field of peak performance (Wright *et al*., 2012).

1.2 Problem statement

Several rugby laws and amendments were introduced after the 2007 Rugby World Cup and several of these laws were applied in the 2008 South African Currie Cup tournament. To date it has not been established how these changes to the laws have affected the physical profile of match play. According to Eaves and Hughes (2003), coaches and trainers should adapt their training programmes to accommodate and take advantage of changes in the profile of the game. This implies that, if the impact of the law changes is analysed, coaches and trainers can adapt their training programmes regularly to improve performances during training and match play.

1.3 Aim of the study

The primary aim of this study is to use computerised notational analysis (CNA) to compare the 2007 and 2013 seasons of the South African Currie Cup tournament in order to determine if

there were any effects that could be attributed to the law changes, on selected performance indicators.

The specific objectives of each article are as follows:

Research article one: Compare the 2007 and 2013 seasons of the South African Currie Cup tournament in order to determine the effect of the law changes on the scoring, time interval, general skills and contact profiles.

Research article two: Compare the 2007 and 2013 seasons of the South African Currie Cup tournament in order to determine the impact of law changes on time variables.

1.4 Motivation for the study

The analysis of rugby matches to determine the effect of law changes and amendments in rugby will give coaches, trainers and players a better understanding of the physical demands made on players during match play. Such analysis will also provide practical information that can assist coaches and trainers to adapt their current training programmes and to develop more specific programmes by prioritising the various strength and conditioning components based on the PIs. This could lead to better physically conditioned players for the modern game. Due to limited research on the effect of recent law changes on the physical demands of rugby, it is important to expand the area of research on rugby-specific strength and conditioning and performance analysis.

1.5 Structure of the thesis

The thesis is presented in research article format. The two research articles (Chapters three and four) were prepared according to the guidelines of different journals. Consequently the referencing style used in the different chapters of this thesis will differ.

Chapter One: Introduction and problem statement: The chapter is included herewith in accordance with the guidelines of the *International Journal of Performance Analysis in Sport* (Appendix A).

Chapter Two: Theoretical background. The purpose of this chapter is to summarise the performance analysis literature specifically strength and conditioning aspects of matches, applicable to rugby in order to establish the theoretical background

for this study. The chapter is included herewith in accordance with the guidelines of the *International Journal of Performance Analysis in Sport* (Appendix A).

Chapter Three: Research article one: Changes in the match profile of the South African Currie Cup tournament during 2007 and 2013. This chapter is included herewith in accordance with the guidelines of the *International Journal of Sport Science & Coaching* (Appendix B).

Chapter Four: Research article two: The effect of the law changes on time variables of the South African Currie Cup tournament during 2007 and 2013. This chapter is included herewith in accordance with the guidelines of the *International Journal of Performance Analysis in Sport* (Appendix A).

Chapter Five: Summary, limitations and future research.

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CHAPTER TWO

THEORETICAL BACKGROUND

This chapter is included herewith in accordance with the guidelines of the *International Journal of Performance Analysis in Sport* (Appendix A).

2.1 Introduction

Rugby union (rugby) is a physically demanding game that requires players to participate in multiple contact situations as well as short, high-intensity sprints (Gabbett *et al.*, 2008). Players are expected to have high levels of physical fitness (i.e. speed, agility, strength and power) and skill (i.e. handling, kicking, tackling) to tolerate the demands and perform well in both in attacking and defending situations (Jarvis *et al.*, 2009; Gabbett *et al.*, 2008). Since rugby became a professional game in 1995, the science of examining the players' characteristics and game tactics has rapidly grown. The use of technology in particular, has assisted with developing and understanding new methods and processes of training (James *et al.*, 2005; Duthie *et al.*, 2003). Performance analysis (PA) has become increasingly accessible across all levels of rugby (Wright *et al.*, 2012). This has allowed for more comprehensive analysis of individual and team performances.

Many changes have been implemented to increase the appeal of the game. This has subsequently led to the introduction of law changes and amendments, particularly after the 2007 Rugby World Cup (IRB, 2013; Austin *et al.*, 2011; Eaves *et al.*, 2008; IRB, 2008). The evaluation of these changes has primarily focused on technical and tactical aspects of the game and very little on the physical profile and its implications for the coaching and conditioning of the players (Wright *et al.*, 2012; O'Donoghue, 2006, Hughes & Bartlett, 2002). With the potential of the match profile to change, due to the implementation of these new law changes and amendments, it is important for coaches and trainers to identify and understand the physical demands of the current game in order to design and implement effective training programmes that meet the specific demands of the modern game (Smart *et al.*, 2014; Vaz *et al.*, 2013; Quarrie *et al.*, 2013; Eaves *et al.*, 2008; Van Rooyen *et al.*, 2008).

Therefore, the purpose of this chapter is to summarise the PA and strength and conditioning literature in rugby in order to establish the theoretical background for this study. This review will firstly give the background on rugby, the effect of professionalism and the introduction of law changes. Secondly, the key functions and processes of PA and the various physical attributes required of rugby players will be stated and lastly, the role PA plays in the coaching process will be identified.

2.2 Rugby Union

2.2.1 Background

Rugby is played worldwide, with the International Rugby Board (IRB) governing the game and the way it is played (Biscombe & Drewett, 2010; Duthie *et al.*, 2003). The game is played over two 40-minute halves separated by a break of 10 minutes to 15 minutes. The stoppages in the game are primarily due to: a) players committing an infringement of the game laws b) players sustaining an injury being replaced or substituted and c) the referee consulting with the assistant referees (Biscombe & Drewett, 2010; Duthie *et al.*, 2003).

Rugby caters for a variety of players. The range of skills and physical qualities required are what makes it a unique game. The variety occurs because the game is based on two key principles: a) contesting possession of the ball and b) continuing play (IRB, 2007). Maintaining the balance between contesting possession and continuing play is what makes the game challenging and unique. The skills required for contesting possession and continuing play differ as each principle requires a certain set of skills in order to be effective (IRB, 2007). This has led to players specialising in certain aspects of the game. Both teams contest for the ball, each having 15 players on the field at any time (except when players have been sent off due to misconduct). Each player is assigned a number and position recommended by the IRB, as seen in Table 1. The positions are grouped according to the specific roles they play in the game. The two major groups are the forward players (forwards), who are the ball winners, and the backline players (backs) or ball carriers (Biscombe & Drewett, 2010). Each of these positional groups requires specific physical (anthropometrics) and physiological (strength, power, speed, agility) characteristics that help them perform their individual roles (Smart *et al.*, 2014; Smart *et al.*, 2013; Jarvis *et al.*, 2009).

Contesting for possession begins at the set pieces (scrums, line-outs and kick restarts) and special play (penalty and free kicks). Scrums and line-outs are pure physical contests, with scrums demanding strength and power and line-outs demanding explosive power and agility, all of which are performed by the forwards (IRB, 2007; Duthie *et al.*, 2003). Once the ball has been gained by a team and is in play, contesting possession will then take place immediately after a player has been tackled and at the breakdowns (rucks) (IRB, 2007). The result of contesting possession and drawing opponents to a contest is the creation of space, which is needed to continue play. Once space has been created, attacking players (primarily backs) use evasive running patterns to move into and around these spaces. These evasive manoeuvres

require players to be fast and agile to gain an advantage over their opponents (Sayers, 1999). Therefore, the game is one in which contesting for the ball creates space to continue play. The game is governed and analysed based on these principles of contesting for possession and creating space to continue play (IRB, 2007).

Table 2.1: Player groups and positions (IRB, 2007; Duthie *et al.*, 2003)

Positional group	Positional subgroups	Position number	Position name
Forward players	Tight five	1	Loose-head prop
		2	Hooker
		3	Tight-head prop
		4	Left lock
		5	Right lock
	Loose forwards	6	Blind-side flanker
		7	Open-side flanker
		8	Eighth man
Backline players	Inside backs	9	Scrum half
		10	Fly half
		12	Inside centre
		13	Outside centre
	Outside backs	11	Left wing
		14	Right wing
		15	Fullback

Traditionally, the forwards and backs have been assigned position-specific roles and duties to perform during match play; however, the significant development of physical attributes by all playing positions and the introduction of new law changes aimed at enhancing the appeal of the game have resulted in a shift towards blending these roles (Fuller *et al.*, 2013; Jarvis *et al.*, 2009). The backs' traditional requirements of speed, change of direction and handling skills remain unchanged; however, with the increased necessity for securing the ball, there is the additional demand of strength particularly in the upper body (Jarvis *et al.*, 2009). The forwards' traditional short, high-intensity bouts of activity to compete for the ball must now incorporate longer sprint durations, with the ball in open play, along with more evasive manoeuvres and handling skills (Jarvis *et al.*, 2009).

Wheeler *et al.* (2010) explored effective attacking strategies in rugby and identified tackle-breaks as a key determinant of try-scoring ability and team success. Furthermore, the execution

of a side step at certain angles and straightening the running line were associated with tackle-breaks. The change in physical characteristics and the blending of positional roles can be attributed to the introduction of professionalism to the game, which will be discussed in the next section.

2.2.2 Professionalism in rugby union

Since rugby became a professional game in 1995, pressure from the public and media for team and individual success has increased. This pressure has not only been felt by the players and coaches but also by the team's management and support staff (Smart *et al.*, 2013). To meet the demand for consistent and successful performances, research on the players' physical characteristics and the analysis of teams and game tactics has rapidly grown (James *et al.*, 2005; Duthie *et al.*, 2003).

With professional status, rugby has developed into a faster, more dynamic physical sport, which means players are involved in more frequent and powerful contact situations (Austin *et al.*, 2011; Eaves & Hughes, 2003; Van Rooyen *et al.*, 2008). As a result, professional rugby players are being exposed to greater training loads and, due to commercial pressure, participate in increasing numbers of competitions. Decreased recovery time between games and competitions along with a shortened pre-season (Van Rooyen *et al.*, 2008) are also a consequence of professionalism.

Eaves and Hughes (2003) identified the patterns of play in international rugby union teams before and after the introduction of professional status. They found that players are performing game activities (passing, tackling, rucking) significantly more quickly and more frequently, while total game activity has also increased. Similarly, the frequency of rucks has increased and although the speed of ball recycling has been consistent. The results suggest that the patterns of play may have shifted towards a faster, ruck-dominated game with more phases of play. The authors concluded that the game has become more physically demanding since the introduction of professionalism.

The continued development of rugby and the increasing competitiveness of the game have led to greater emphasis on the use of technical and scientific support to aid the coaching process. This has led to the development of specialised coaches, each contributing to a specific aspect

of the game (James *et al.*, 2005). The roles of strength and conditioning coaches and performance analysts in particular, have become prominent in team coaching structures across many levels of rugby (Wright *et al.*, 2012). Teams are beginning to identify and understand the benefits of such coaches and services as they allow more specific training and conditioning programmes to be implemented (Duthie *et al.*, 2003).

2.3 South African Currie Cup

South Africa has a proud rugby tradition, with the Currie Cup tournament being one of the oldest domestic rugby competitions, dating back to 1892 (Louw, 2010). The Currie Cup takes place annually between August and October. The 2014 format divided the 14 provincial unions into eight teams in the Premier Division and six in the First Division. Similar to the Vodacom Cup, which takes place earlier in the year, the Currie Cup is a platform for young, talented players to perform in a professional environment (Louw, 2010). With the introduction of the Super Rugby competition, and the purpose of the tournament now shifting towards developing South African rugby talent, the South African Rugby Union (SARU) has expanded the league towards the younger age groups, establishing an Under 19 and Under 21 tournament.

To the researcher's knowledge, limited studies have been conducted using the Currie Cup tournament as a sample. The majority of studies utilise data from the international competitions in which professional South African rugby teams are involved, i.e. the Super Rugby competition, the Rugby Championship, Springbok international test matches and the Rugby World Cup (Hendricks *et al.*, 2013; Van den Berg & Malan, 2012; Van Rooyen *et al*., 2010; Van Rooyen *et al.*, 2008, Williams *et al*., 2005). Studies involving the Currie Cup tournament have generally been limited to incidences of injuries (Millson *et al.*, 2005). Millson *et al.* (2005) reported on the nature and incidence of injuries in a Currie Cup rugby team over three consecutive seasons (2001-2003). The authors found the number of injuries increased as the season progressed; however, there was a reduction in the overall injury rate over the three seasons thanks to the development in the training and medical departments.

Pretorius *et al.*, (1999) investigated the 1997 Currie Cup season and found teams performed better when they had the home-ground advantage. With a small number of unions competing in the tournament, this may be one of the reasons why the format of the competition was subsequently changed.

2.4 Law changes in rugby union

Background

Law changes are fundamental to the development of sport and are introduced for several reasons (Kraak & Welman, 2014; Eaves *et al.*, 2008). Some of these reasons are, among others, in response to player performance, to ensure safety, enhance participation and enjoyment, promote game continuity, technological advancement and commercial pressures, as well as to retain game integrity and development (Eaves *et al.*, 2008; Williams *et al.*, 2005).

The laws of rugby are developed and amended by the IRB. The IRB constantly reviews and, when necessary, changes the laws to ensure safe, enjoyable and entertaining rugby events are delivered (Biscombe & Drewett, 2010). Thus, with the changing profile of the sport, the training of players cannot remain the same. There needs to be a constant and necessary evolution of training and assessment methods in rugby, as this is required to continuously improve the physical attributes of players to meet the changing profile and position-specific demands (McMaster *et al.*, 2013; Vaz *et al.*, 2013).

Since 1995 rugby has become more business oriented, with the financial viability of the sport becoming greatly concerned with crowd attendance and broadcasting rights (Van den Berg & Malan, 2012). Previous research has found that fast, dynamic and physical matches attract spectators, which in turn leads to significant commercial value (Van den Berg & Malan, 2012; Eaves & Hughes, 2003). The IRB's introduction of experimental law variations (ELV) to make the game more attractive and reduce the number of match-related injuries was welcomed (Van den Berg & Malan, 2012) by the business sector.

2.4.1 Law changes

The changes and amendments introduced during 2007 and 2013 are listed in Table 2.

Table 2.2: Law changes and amendments after 2007 (IRB, 2013; IRB 2007)

Law Topic	**Current Law**	**Amendment/Change**
Law 3.4: Players nominated as substitutes	For international matches a Union may nominate up to seven replacements/substitutes.	For international matches a Union may nominate up to eight replacements/substitutes.
Law 6.A.6: Referee consulting with others		Extension of the jurisdiction of the television match official (TMO)
Law 9.B.1 (e): Taking a conversion kick	The kicker must take the kick within one minute from the time the kicker has indicated an intention to kick. The intention to kick is signalled by the arrival of the kicking tee or sand, or the player makes a mark on the ground. The player must complete the kick within one minute even if the ball rolls over and has to be placed again.	The kick must be taken within one minute and 30 seconds (90 seconds).
Law 12: Outcome of a knock-on or throw forward Add new 12.1 (e) Current Law 12.1 (e) becomes 12.1 (f)		Knock-on or throw forward into touch. When the ball goes into touch from a knock-on or throw forward, the non-offending team will be offered the choice of a line-out at the point the ball crossed the touch line, or a scrum at the place of the knock-on or throw forward. The non-offending team may exercise this option by taking a quick throw-in.
Law 16.7: Unsuccessful end to a ruck Add new 16.7 (c)		When the ball has been clearly won by a team at a ruck and the ball is available to be played the referee will call "use it", after which the ball must be played within five seconds. If the ball is not played within the five seconds the referee will award a scrum and the team not in possession of the ball at the ruck will be awarded the throw-in.
Law 17.6: Unsuccessful end to a maul Added new 17.6 (g)		If the ball carrier in a maul goes to ground, including being on one or both knees or sitting, the referee orders a scrum unless the ball is immediately available.

		When the ball is available to be played the referee will call "use it", after which the ball must be played within five seconds. If the ball is not played within the five seconds the referee will award a scrum and the team not in possession of the ball at the ruck will be awarded the throw-in.
Law 19.2: Quick throw-in	For a quick throw-in, the player may be anywhere outside the field of play between the place where the ball went into touch and the player's goal line.	For a quick throw-in, the player may be anywhere outside the field of play between the line of touch and the player's goal line.
Law 20.1 (g): Forming a scrum		The referee will call "crouch" then "touch". The front rows crouch and, using their outside arm, each prop touches the point of the opposing props outside shoulder. The props then withdraw their arms. The referee will then call "set" when the front rows are ready. The front rows may then engage. The "set" call is not a command but an indication that the front rows may come together when ready.
Law 21.4 Penalty and free-kick options and requirements Add new 21.4 (b) Current 21.4 (b) to (k) become (c) to (l)		Line-out alternative. A team awarded a penalty or a free kick at a line-out may choose a further line-out (their throw-in). This is in addition to the scrum option.

2.5 Performance analysis

2.5.1 Background

PA involves assessing performance to evaluate the effectiveness of the strategies of teams or individuals in a sport. Through the analysis of movements and patterns of play, coaches, specialist coaches and players are able to interpret and understand various situations in the game (Hughes & Bartlett, 2002). This process has also been described as a combination of biomechanics and notational analysis in the study of how movements relate to sports performance (Bartlett, 2001). PA generally involves analysis of a match performance; however, if a particular skill is critical to the sport, for example the kick at goal, then PA can also be conducted in a practice setting (O'Donoghue, 2006). It is therefore considered to be on a continuum, depicted by the researcher in Figure 2.1, ranging from technical analysis of an individual's closed skills (biomechanics orientation) at one end through to game analysis (notational analysis and time-motion analysis orientation) at the other. Research on PA in rugby has explored aspects of the game, such as patterns of play, analysing breakdowns, analysing technical skills and identifying physiological estimates of players' work rates (Hendricks *et al.*, 2013; Quarrie *et al.*, 2013; Van den Berg & Malan, 2012; Austin *et al.*, 2011; Van Rooyen *et al*., 2010; Van Rooyen *et al.*, 2008).

Figure 2.1: Performance analysis continuum

2.5.2 Performance indicators

The computer-based software that analyses performances using video image is highly customisable and can be tailored to analyse any aspect of the game using Performance Indicators (PIs) (O'Donoghue, 2006). PIs are a selection, or combination, of action variables that aim to define some or all aspects of a performance. In order for the PIs to be useful, they should relate to successful performances (James *et al.*, 2005; Hughes & Bartlett, 2002). Four categories of PIs have been proposed for use in performance analysis of sport: *match classification indicators*, *tactical*

indicators, *technical indicators*, and *biomechanical indicators* (Hughes & Bartlett, 2002). Such indicators can be applied to an individual player or team.

Match classification indicators report the frequency of key structural events within a game. Examples within rugby include scoring (tries, penalty kicks and drop kicks), line-outs, scrums and turnovers. Sasaki *et al.* (2007) analysed the scoring profile and defence performance in the Japanese domestic competition from 2003 to 2005. The results indicated that the number of points decreased over the three seasons and that most tries (over 50%) came from scrums and line-outs. There was an increase in the number of tackle turnovers, which suggested that there had been improvements in defence performance by teams. Vaz *et al.* (2012) analysed the effect of alternating home and away field advantages on selected PIs during the Six Nations Rugby Championship (2005-2009). The results revealed that there was a tendency for teams that played at home to achieve better results. Significant differences were seen in the number of penalty kicks and the success thereof, the number of rucks/mauls won and the number of passes completed. The results also indicated that 50% or more of the total points scored were scored when teams played at home. The authors concluded that there was a tendency in the Six Nations Rugby Championship (2005-2009) teams achieve favourable results when playing at home.

Technical indicators reflect the level of success at performing a specific skill. Any error or success frequencies should be normalised against the total number of times the technical skill was attempted, and represented as a percentage or ratios (Hughes & Bartlett, 2002). Examples in rugby include percentage of successful kicks at goal, line-out throws won, tackles made and missed, successful passes completed, handling errors and total number of turnovers. Van Rooyen *et al.* (2010) evaluated the 2007 Rugby World Cup tournament to determine whether ruck occurrence could predict successful performance. The authors found that the knockout stages of the tournament had a greater number of rucks per game (121 range 71-164) than the pool stages (116 range 65-172). Matches during the pool stages were won (58%) by teams with the highest number of rucks. In the knockout stages the team with the fewest rucks won 100% of the matches. The data suggests that during the pool stages of the tournament, the greater the number of rucks a team creates, the more likely it is to win the match, yet it was not effective during the knockout stages of the tournament where avoidance of rucking was associated with success.

Vaz *et al.* (2010) identified rugby game-related statistics that discriminated between winning and losing teams in IRB and Super 12 close games (2003-2006). The results were able to distinguish between winning and losing teams by possessions kicked, tackles made, rucks, turnovers won, passes completed, errors made and kicks to touch. The results suggested that a kicking-based game supported by an effective defence structure was more likely to win matches than a possession-based approach.

Tactical indicators reflect the style of play of the individual player or teamwork of units, by indicating the options taken at certain interchanges of the game. They may also reflect the pace, fitness and movements and the ability to target specific technical strengths and weaknesses of opponents. In rugby, tactical indicators include percentages or ratios to represent the options of passes, kicks and tackles, and the number of players committed to attacking or defending situations. Prim *et al.* (2006) compared various performance parameters (ball possession, tries scored, PIs associated with successful ball retention and effectiveness of tackle situations) of the four SA Super Rugby teams and the winners of the 2005 Super 12 tournament. The results revealed no significant differences between the teams' ball possession, tries scored or numbers committed to the breakdowns; however, there were noticeable differences between the styles of play of the teams. The winners of the tournament had the lowest defensive and offensive recycling times, which indicated a higher tempo of play. Despite the winning team conceding a similar number of tries to the SA teams they scored the most tries, thus their attack might have been key to their success.

Wheeler *et al.* (2013) examined the association between defensive strategies and ruck outcomes in rugby. Defensive tactics at the ruck contest were analysed during 60 games of the 2011 Super Rugby competition. The variables described were the attacking width, territory gained by the attack, defensive strategy used at the ruck, and ruck outcome. The analysis showed that both early counter-ruck (competing for the ball without hands) and jackal (competing for the ball with hands) were effective at turnover possession behind the advantage line (60% and 39% respectively). Early counter-ruck was also effective at turning over possession when ruck contest occurred in the wide attacking channels (18%), while a jackal was used at ruck contests occurring in the central field (13%). Late counter-ruck was a poor strategy as it was more likely to concede a penalty.

Biomechanical indicators concentrate on mechanically breaking down technical skills and identifying specific movements crucial to the successful execution of the technique. Technical skills that could potentially benefit from such analysis in rugby include evasive running (side stepping or swerving), kicking, passing, tackling, line-out jumping and support and hooker throwing. This analysis allows coaches and trainers to achieve a better understand of the various information-processing aspects of the game, including the control and coordination of complex multi-segmental movements. Wheeler and Sayers (2011) examined the running technique of eight highly trained rugby players during three rugby-based reactive agility conditions (non-contact, contact and fend). The results demonstrated that there was a deduction in the relative height of the centre of mass (% CM) at the straighten step during contact conditions, compared to the non-contact conditions. The fend condition was then shown to increase the % CM at the straighten step when compared to the contact condition. Further analysis showed the number of steps displayed between the side step and straighten step (transition phase) altered the % CM, with one step increasing the % CM compared to two steps or no transition phase steps. The change in running technique during agility conditions involving tackle situations highlighted the importance of running programmes that meet the specific demands of match play activities.

2.5.3 Performance profiling

Developing and utilizing PI can lead to the creation of performance profiles for specific sporting codes. Performance profiles are a description of a pattern of performance from an individual or team and are created from collected frequencies of PI. Such profiles can lead to a better understanding of situations and tactics implemented by teams which offers some prediction to future performances (Robertson & Joyce, 2014; Jones *et al.*, 2004). However, according to O'Donoghue (2006) when developing profiles, choosing the correct PI to analyse sport is crucial. Examples of tasks in rugby include goal kicking and cover tackling, which could then be grouped with other similar actions, into skill sets such as kicking and defence. Groups of four or five key PI have can then are reduced into a single performance measure for a given match. However, these performances cannot be established after a single match (one execution of performance), as performances and execution of skills varies from matches and individuals (Bracewell, 2003).

Rugby is a dynamic and reactive game and situations players are involved in constantly change. Therefore, performance measuring is a long-term effort of monitoring and analysing performances.

Ortega *et al*. (2009) conducted research on the contrasting differences between winning and losing teams in the Six Nations. The author analysed 58 games from 2003-2006 season. The study identified 28 PI and grouped them into 3 performance profiles. The groups of PI were: "points scored", described the number of points scored and the way in which the points were scored, "phase of play", described the way teams obtained the ball and how the teams used it, "game development", described technical and tactical aspects. The results showed that the winning teams had significantly higher PI for points scored, conversions, successful drops, mauls won, line breaks, possessions kicked, tackles completed, and turnovers won. Losing teams had significantly higher PI for scrums and line-outs lost. The results concluded that: a) in the phases of obtaining the ball and more specifically in scrummage and line-out, winning teams lose fewer balls than losing teams (winning teams have an efficacy of 90% in both actions); b) the winning team tends to play more with their feet when they obtain the ball, to utilize the maul as a way of attacking, and to break the defensive line more often than the losing team does c) on defence, winning teams recovered more balls and completed more tackles than losing teams, and the percentage of tackles completed by winning teams was 94%. The performance profiles could be used as a reference for monitoring training and competition performances.

2.6 Strength and conditioning

2.6.1 Background

A field-based contact sport such as rugby is characterised by frequent high-intensity bouts of sprints and high levels of physical contact separated by bouts of low-intensity exercises (walking and standing) (Smart *et al.*, 2013; McLellan & Lovell, 2012; Gabbett *et al.*, 2008). Due to the unique nature of the game, the physical attributes of players are complex and specific to the roles they play in the game (Jarvis *et al.*, 2009). There have been prominent changes in the fitness and physical profile of elite players (Duthie *et al.*, 2003). With the evolution of increasing

competitiveness in rugby, the requirements of bigger, faster and stronger players are becoming ever more apparent (Smart *et al.*, 2014).

Comprehensive studies of rugby strength and conditioning have identified specific physical attributes of players, fitness requirements and movement patterns that have contributed to the development of more effective conditioning programmes (Smart *et al.*, 2014; Quarrie *et al.*, 2013; Austin *et al.*, 2011; Cunniffe *et al.*, 2009). Quarrie *et al.* (2013) analysed the movements and activities of 763 players in over 90 international rugby matches played by the New Zealand national team from 2004 to 2010. The cluster analysis of activities and time-motional variables produced five subgroups of forwards (props, hookers, locks, flanks, number 8) and five subgroups of backs (scrum half, fly half, midfield backs, wings and fullbacks). The forwards experienced significantly higher contact loads per match than backs through scrums, rucks, mauls and tackles. Mean distance covered per match ranged from 5400m to 6300m for all positions, with backs running further than forwards; however, there were differences between positional groups in the distance covered at various speeds.

Research in the field of strength and conditioning has focused on identifying physiological characteristics of players during competition and training. This has led to the introduction of PA tools in the form of time-motional analysis and notational analysis (Quarrie *et al.*, 2013; Austin *et al.*, 2011). With the implementation of technology in rugby, the field of PA seems to overlap with that of strength and conditioning in the pursuit of developing sports-specific conditioning programmes and therefore falls on the same continuum, as depicted by the researcher in Figure 2.2. With the understanding of movement patterns that biomechanics principles provide, and the potential for notational analysis to determine physiological demands during training and competition, PA can help strength and conditioning coaches develop programmes that meet the specific demands of the individual and teams (Gabbett *et al.*, 2008). The following section will cover the physical attributes of rugby players.

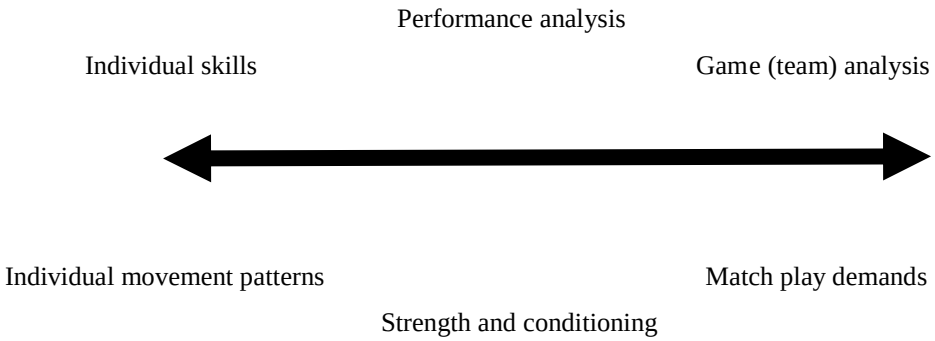

Figure 2.2: Performance analysis and strength and conditioning continuum

2.6.2 Physical attributes of rugby union players

2.6.2.1 Body composition

Body composition and size are important attributes, particularly in contact sports. Rugby is unique in this regard as the sport accommodates athletes of all shapes and sizes (Fuller *et al.*, 2013). In the 1998 New South Wales Super 12 rugby team, the front row (112.8 ± 5.7kg) and the remainder of the forwards (108.3 ± 5.3kg) were significantly heavier than the backs (89.0 ± 6.8kg). Differences were also observed between the positional groups. Hookers (89.7 ± 8.1kg) were found to weigh less than props (102.8 ± 8.1kg). Among the backs, the inside backs (75.0 ± 6.9kg) were substantially lighter than the centre paring (85.9 ± 6.9kg) and outside backs (83.4 ± 6.9kg). A larger body size has correlated significantly with scrumming forces and competition success and body mass is therefore naturally greater for forwards than backs (Duthie *et al.*, 2003).

There have been significant changes in these attributes in rugby over the past decade. Fuller *et al.* (2013) evaluated the changes in the stature, body mass, age and number of players by playing position in the first-team squads of English Premiership rugby teams from 2002 to 2011. The mean stature of players in all positions increased during the period but statistically significant trends were only observed at fly half and prop. While the mean body mass of players increased in most positions only fly half and back-row players showed a significant increasing trends. The average age of players in all positions decreased, but this trend was only significant for the props, while

the number of registered players also increased but the trend was only significant for the props. The authors concluded that during the period the elite rugby players became taller, heavier and younger but statistically significant changes were limited to fly halves (taller and heavier), props (taller and younger) and back-row forwards (heavier).

With matches becoming faster and more open, forwards' participation in the game has demanded a greater need for mobility and this has resulted in lower body fat levels and higher lean body mass being recorded for forwards (Jarvis *et al.*, 2009). This change has filtered through to the technical aspects of the game. An example of this is lowering the centre of gravity and widening the base of support to increase stability. With mass influencing stability, lean body mass assists with such biomechanical aspects (Duthie *et al.*, 2003).

2.6.2.2 Anaerobic fitness

The energy demands during intermittent team sport activities such as rugby are primarily anaerobic in nature. Speed, strength and power are important physical qualities in rugby and are required in the execution of tackles, acceleration, scrumming and forceful movements in rucks and mauls (Smart *et al.*, 2013; Smart & Gill, 2013). There is also a demand for a high anaerobic capacity to sustain repeated high-intensity efforts. In studies analysing rugby movement patterns it has been found that repeated sprints rarely occur during competitions (Gabbett, 2012; Sirotic *et al.*, 2009). However, high-intensity repeated efforts (sprinting and tackling) occur frequently and often before scoring (Gabbett, 2012). This highlights the importance of training an anaerobic capacity and suggests that a repeated sprint and repeated effort may prove critical to match outcomes.

2.6.2.3 Muscle strength and power

Strength is defined as the maximal force produced by a muscle. Power is defined as the product of force (strength) and velocity (speed) (Duthie *et al.*, 2003). Rugby performance requires high levels of muscular strength and power for success, particularly in the areas that involve contact between players, i.e. rucks and mauls, tackles, scrums and line-outs. In the light of this, forwards should possess greater strength than backs as they are required to more frequently compete for the ball in contact situations (Worsnop, 2012).

McMaster *et al.* (2013) assessed the force-velocity-power of semi-professional rugby union players. The analysis of the peak-force and peak-velocity load profiles revealed that the forwards produced significantly greater forces (forwards = 405-1319 N; backs = 328-1096) and backs produced slightly larger (insignificant) velocity (backs = 0.72-2.48 m/s; forwards = 0.62-2.30 m/s) across all relative loads in the exercises. This indicates that stronger forwards are possibly force dominant and the weaker backs are velocity dominant. The authors suggested that the results of the study provide coaches and trainers with detailed information on how to improve players force-velocity (strength-speed) capabilities. Players with less than optimal force (i.e. backs) could attempt to improve their force-velocity profile by conducting heavier ballistic loads, while players with less than optimal velocity (i.e. forwards) should attempt to improve by conducting lighter ballistic loads. Improving these deficiencies would increase the power output of players, as power is the product of force and velocity.

2.6.2.4 Speed and Agility

Speed and agility are crucial skills for any player. Within phase play, players that can get to the ball the fastest, chase down kicks and support line breaks have a distinct advantage over their opponents (Wornsop, 2012). Backs, in particular, have a superior sprinting ability compared to the forwards (Wornsop, 2012). During match play backs have greater space to run and can therefore achieve higher speeds compared to the forwards who regularly compete for the ball, close to the opponents. High levels of running activity are required in both attack and defence for backs as they assume the furthest position in a defence line and act as support players and decoy runners on attack. The slower forwards are either involved in competing for possession at the breakdown, or filling the nearest position in the defensive line (Jarvis *et al.*, 2009). In a review of team sports, Spencer *et al.* (2005) investigated the physiological and metabolic responses of repeated sprint exercises. They reported that the mean distance and duration of sprints were between 10 to 20 metres and 2 to 3 seconds respectively. Similar results were found in rugby league players. Gabbett (2012) analysed sprinting patterns of national rugby league players and found that the majority of sprint efforts (67.5%) were performed over < 20m. The most common sprint distance for forwards was 6-10m (46.3%). Outside backs had a greater proportion (33.7%) of sprint efforts over sprint

distances of ≥ 21m. Of the sprints performed 48% involved contact, 58% were preceded by forward movement (walking, jogging, striding) and 24% were preceded by a standing start. The majority of sprint efforts were performed without the ball (78.7% vs. 21.3%). Most sprint efforts (67.5%) were followed by long periods of recovery ≥ 5min. The outside backs had the greatest proportion (76.1%) of long-duration recovery periods and the smallest proportion (1.8%) of short-duration recovery periods (< 60s) between sprints. These results highlight the differences between the positional groups in terms of the nature of sprint efforts and distance covered. Furthermore, the activity preceding and the recovery after sprint efforts also highlight differences between playing positions. These findings suggest that training programmes should be tailored to meet the demands of the specific positional groups.

Speed and agility are also qualities that allow players to maintain continuity in contact and therefore keep the game flowing (Worsnop, 2012). The ability to execute evasive running skills, i.e. hit and spin and offload out of the tackle and side step opponents, is associated with agility. The ability to beat another player has been significantly associated with acceleration (20m and 40m sprint distances), reactive agility and vertical jump height (Worsnop, 2012). Research on speed and agility has found that both physical qualities should be treated separately as straight-line speed does not improve performance in sprints with change of direction (Jarvis *et al.*, 2009). Said authors investigated agility performance of rugby players and identified differences between the positional groups. Results indicated that backs produced significant correlations in agility performance compared to forwards. The findings indicated that the use of rugby-specific agility programmes to improve agility performance would be of greater benefit and higher priority to backs than forwards.

2.6.3 Work capacity

Timing the duration of activities and calculating work-to-rest ratios provide an objective means of quantifying the physiological requirements of an activity (Duthie *et al.*, 2003). Deutsch *et al.* (2007) quantified the movement patterns of various positions during professional rugby union match play, such that the relative importance of aerobic and anaerobic energy pathways to performance could be estimated. A professional rugby team was used during the 2006 Super 12 Rugby tournament. The results indicated significant demands on all energy systems in all playing

positions, yet implied a greater reliance on anaerobic glycolytic metabolism in forwards, due largely to regular involvement in non-running intense activities, i.e. tackling, rucking, mauling and scrumming. Positional group comparison indicated greater differences between the forwards and backs - each positional group had its own unique demands. Front-row forwards and back-row forwards were mostly involved in activities involving gaining/retaining possession (80-90%). Back-row forwards tended to play a pseudo back-line role, performing less ruck/mauling than front-row forwards, yet were involved in more aspects of broken play such as sprinting and tackling. Inside backs and outside backs tended to specialise in the running aspects of play (60-70%), yet the inside backs showed greater involvement in confrontational aspects of play such as rucking/mauling and tackling. The forwards performed more high-intensity work than the backs (7.4 ± 1.4 vs 21.8 ± 7.5) due to the forwards performing more frequent activities and backs having longer rest periods. The maximum sprint durations revealed that inside backs (5.2 ± 1.0s) and outside backs (7.2 ± 1.9s) were required to perform regular sprint distances of 40m to 60m, while the front-row forwards (3.2 ± 1.8s) and back-row forwards (3.4 ± 1.9s) were required to perform sprint distances of 10m to 15m. These results suggest that rugby training and fitness testing should be tailored specifically to the positional groups.

2.7 The role of performance analysis in the coaching process

With the evolution of competitive rugby and the ever-growing need to gain the competitive edge over the opponents, coaching structures now demand the services of specialist coaches to assist with the training and analysing of performances. PA involves categorising the events or actions that have occurred in a match, enabling coaches and specialist coaches to create an objective and statistical account of the match to use when giving feedback (Carling *et al.*, 2008). The role of PA in the coaching process is to provide additional feedback to players and coaches, based on a systematic and objective analysis, and to identify technical, tactical and physical strengths and weaknesses of individuals and teams. The strength and conditioning coach applies scientific knowledge to interpret and implement the feedback supplied by PA to physically strengthen individuals and teams, and to ensure the training matches what is required of match play. Coaches, as well as specialist coaches, identify successful and unsuccessful technical and tactical strategies implemented by both teams in an attempt to identify trends and possibly flaws in tactics. All this information is provided by the PA.

The coaching process compromises a number of steps or cycles. The importance of analysing play is highlighted in Figure 2.3, which outlines the coaching process in its observational, analytical and planning phases. The match or training session is watched (observational phase) and the coaches will identify the biomechanical/technical/tactical/physical strengths and weaknesses (analytical phase) of the performance during practice or matches. The results of previous matches and training loads during training sessions are always considered before planning and preparing (planning phase) for the next match and training session. Strength and conditioning coaches carefully monitor training loads/volumes and recovery of players after matches and training sessions as recovery plays a major role in acquiring certain physiological adaptations and facilitating physiological peaks. Once the next match or session is performed, the process repeats itself (Franks, 2004).

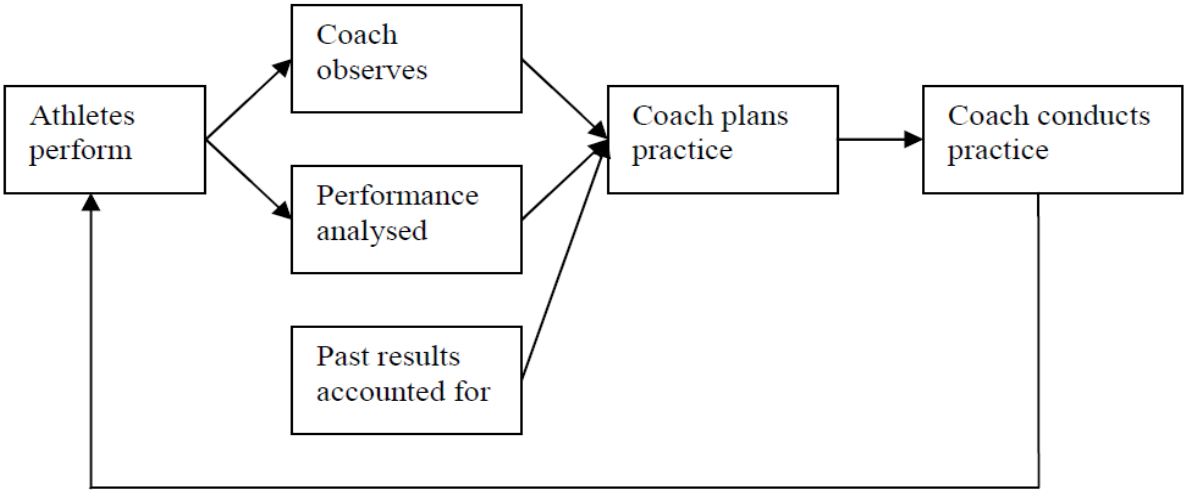

Figure 2.3: The coaching process (Franks, 2004)

2.8 Summary

The purpose of this chapter was to summarise the PA and strength and conditioning literature in rugby in order to establish the theoretical background for this study. With the introduction of professionalism in 1995, the game has rapidly and continuously changed. One such change has been the introduction of several law changes to enhance the appeal, continuity and safety of the game. Research investigating the effects of these law changes has primarily focused on the technical and tactical aspects of the game and very little on the changes to the physical profile of match play. From the literature reviewed, it is clear that the physical demands of the game need to

be analysed regularly to assist coaches, trainers and players in understanding the modern game. There needs to be a constant and necessary evolution of training and assessment methods in rugby to continuously improve the physical qualities of the players and teams to match the growing sport. The physical demands of competition have been investigated by means of time-motion analysis, notational analysis and global positioning systems (GPS). The development of notational analysis and the identification of PIs have allowed for detailed information by analysing specific technical, tactical and physical profiles of teams in various tournaments. The development of these profiles will lead to a better understanding of various situations; however, limited research has been done on the development and use of these profiles in a rugby-specific manner.

Thus, with the use of technology to analyse performances rapidly increasing, and the need to determine the changing profile of rugby, the training of players must adapt to and accommodate the law changes and the effects thereof on the physical demands of the game. It has been well established that the physical demands of the game need to be monitored and revised in order for effective training programmes to be compiled.

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CHAPTER THREE

RESEARCH ARTICLE ONE:

CHANGES ON THE MATCH PROFILE OF THE SOUTH AFRICAN CURRIE CUP TOURNAMENT DURING 2007 AND 2013

This chapter is included herewith in accordance with the guidelines of the *International Journal of Sport Science & Coaching (Appendix B).*

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Changes on the match profile of the South African Currie Cup Tournament during 2007 and 2013

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Changes on the match profile of the South African Currie Cup Tournament during 2007 and 2013

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ABSTRACT

In rugby union, several law changes were implemented between 2007 and 2013, yet the impact of these law changes on the profile of the game has not been assessed to date. The aim of this study was to determine the effect of the law changes on the scoring, time interval, general skills and contact profiles of the South African Currie Cup during the 2007 (n = 37) and 2013 (n = 33) seasons. A total of 70 matches were analysed using video analysis software. The frequencies of 37 performance indicators were used to address the aim of the study. The scoring profile revealed that fewer tries were scored ($p = 0.07$), while the number of penalty goals increased significantly ($p < 0.01$). The time interval profile showed that stoppages decreased significantly ($p < 0.01$). The skills profile revealed a significant increase in the number of passes ($p < 0.01$) and a decrease in the number of handling errors, offloads and kicks ($p < 0.01$). The contact profile revealed a significant increase in the number of rucks/mauls and tackles completed ($p < 0.01$) and a decrease in scrums and line-outs ($p < 0.01$). The study revealed that the South African game has more physical and continuous.

Key words: Performance indicators, law changes, performance analysis, physical demands

3.1 INTRODUCTION

Since rugby union (hereafter referred to as rugby) became professional in 1995, the science of examining the sport and its participants has rapidly grown and developed to meet the increasing demand for knowledge on game tactics and player characteristics [1]. With the continued development of professional sport, the use of technology and scientific support is becoming increasingly emphasised to aid coaches, specialist coaches and trainers in the coaching process and within coaching structures as it provides them with detailed information on performances of individuals and teams and is accessible across all levels of rugby [2, 3].

The profile of rugby is constantly changing as technology has allowed coaches to push the boundaries of the laws and the way in which match play is scrutinised [4]. Many of the changes implemented have been to increase the appeal and competitiveness of the game, which has subsequently led to the introduction of several law changes and amendments, especially between 2007 and 2013 [5]. Since performance analysis (PA), more specifically notational analysis, objectively records events during performances and can be used to map playing patterns and game structures, it serves as the best method to analyse any changes that may occur in the match profile [4, 6]. The problem that occurs during the changing of laws is that the legislators primarily focus on the technical and tactical aspects of the game and very little on the effect of the changes on the physical aspects of the game. Research investigating rugby law changes or amendments has generally been limited to studies of specific technical and tactical aspects of the game, and very little has been done to explore the physical profile and conditioning aspects associated with the changes [3, 7, 8, 9].

Williams *et al.*, [10] and Eaves and Hughes [11] identified changes that occurred in the game and found that the total match time, ball-in-play time as well as ruck frequency increased significantly. It was speculated that an increase in match times and continuity might lead to increased player actions. It was suggested that these findings were largely due to the law changes introduced over the period of the research. Van den Berg & Malan [6] investigated whether the experimental law variations (ELVs), introduced in 2008, were

effective in making rugby matches more appealing to spectators by improving continuity. The authors analysed all the Super 14 teams that participated in the 2006 and 2008 tournaments and found the number of scrums and line-outs had decreased but the number of tackles made, metres gained and penalties conceded had all increased significantly. The authors concluded that the increase in player activities that promoted continuity suggested that the ELVs implemented had succeeded in increasing the appeal of the game. It has therefore been well established that the game has become more physically demanding; however, the studies fail to mention the law change implication on the physical profile of the game or the training implications it has on players or teams. Duthie *et al*. [1] compiled a review study on the physiological demands on rugby players and the use of PA. They analysed the physical characteristics (body mass, height, muscle-fibre types) and physical capacities (maximal oxygen uptake, anaerobic performance, muscle strength and power and speed) of rugby players. The authors also suggested that law changes have made the play "more open" and faster and that the data they collected may not accurately reflect the current game due to the changes to the game's profile. Thus, with the changing profile of the game, conditioning of players cannot remain the same and training programmes must adapt to and accommodate the law changes and the effects thereof on the physical demands on players. Such changes need to be monitored and considered in the design of training programmes in order to gain the competitive edge.

Research clearly shows that the physical demands on the players need to be monitored in order to draw up effective training programmes [1, 5, 11, 13]. More comprehensive research on the physical characteristics of players, fitness requirements and movement patterns of rugby needs to be undertaken, and research on how coaches and trainers can implement performance analysis in the coaching process is still limited. It has been made clear that there is a "gap" between research and coaching practice, especially within the field of peak performance [9]. Therefore the aim of this study was to compare the 2007 and 2013 seasons of the South African Currie Cup tournament in order to determine the effect of the law changes on the scoring, time interval, general skills and contact profiles.

3.2 METHODOLOGY

SAMPLE POPULATION

The video recordings of the South African Currie Cup rugby tournament during the 2007 and 2013 rugby seasons were used for the purpose of this study. A total of 70 matches were analysed, 2007 (n= 37) and 2013 (n=33).

PROCEDURE OF TESTING

The video recordings of the Currie Cup matches were supplied by Fika, the official analyst company of the tournament. The matches were analysed using Dartfish 6.0 TeamPro software package. The video files were viewed and coded in the software's tagging panel. A tagging panel was created by the researcher, who is a qualified Dartfish tagging and video analyst. The panel allows a key press to translate into a PI. To provide a detailed analysis, several PIs are entered into the panel. To ensure acceptable reliability, intra-observational tests were undertaken for all variables with the level of agreement exceeding 95%. For intra-observational procedures, the analyst randomly selected 25% of matches and viewed them under the same conditions. Ethical approval was obtained from the Research Ethics Committee: Human Research, Stellenbosch University (REC-050411-032).

PERFORMANCE INDICATORS

Table 3.1 shows the PIs analysed based on the law changes and amendments.

Table 3.1 Performance indicators and definitions of the scoring, general skills, time interval and contact profile

Performance Indicator	Definitions
Scoring profile	
Total points scored	The total number of points scored.
Tries scored	The total number of tries scored.
Source of try	Actions or set pieces that led to the try-scoring team attaining possession of the ball. This can be achieved through the following: scrum, line-out, open play (counterattack from opponent error, counterattack from tackle turnover, counterattack from kick).
Conversions (successful/missed)	The total number of conversion kicks attempted and whether they were successful or missed.
Penalty kicks (successful/missed)	The total number of penalty kicks attempted and whether they were successful or missed.
Drop kicks (successful/missed)	The total number of drop kicks attempted and whether they were successful or missed.
General skills profile	
Passes completed	The total number of successful passes. A pass was considered successful if a player from the same team caught the ball without dropping it.
Handling errors	The total number of unsuccessful passes. A pass was considered unsuccessful if a player from the same team dropped the ball or knocked the ball forward.

Offloads in the tackle	The total number of offloads. An offload was when a player was tackled with the ball but successfully passed the ball before the tackle was completed.
Kicks	The total number of kicks performed by any player. The ball making contact with the player's foot was considered a kick.
Time interval profile	
Stoppages	The total number of stoppages in the match. A stoppage occurred when the ball was outside the playing field and remained there, or when the referee blew the whistle to indicate a stop in play.
Injuries	The total number of injuries. An injury was considered as having occurred when a player on the field immediately stopped playing and required medical attention before continuing to play or being removed from the field.
Replacement/Substitute	The total number of replacements and/or substitutes. A replacement was made for an injured player and a player was substituted for tactical reasons. A replacement was not allowed to rejoin play unless he was temporarily replaced to have bleeding controlled. A substituted player could rejoin play temporarily to replace a player that had sustained a blood injury or if he was to replace a front-row player.
Contact profile	
Rucks/Mauls (Win/Lose)	The total number of rucks and mauls that occurred and whether the attacking team successfully retained possession of the ball or knocked it forward. A ruck was when the ball was on the ground and two opposing players made contact over the ball. When a player with the ball was

	held up, without being tackled, by an opposing player and a player from his own team, if was considered a maul.
Scrums (Win/Lose)	The total number of scrums that occurred and whether the attacking team (team that fed the ball into the scrum) successfully retained possession or lost possession.
Line-outs (Win/Lose)	The total number of line-outs that occurred and whether the attacking team (team that threw the ball in the line-out) successfully retained possession of the ball or lost it in the contest.
Total tackles	The total number of successful tackles that occurred. When one or more opposing players made contact with the ball carrier and successfully brought him to the ground, it was considered a successful tackle.
Single tackles	The total number of single tackles that occurred. A single tackle was when a tackle was completed by a single player without assistance from any teammate.
Double tackles	The total number of double tackles that occurred. When a tackle was completed by two players, with both notably contributing to grounding the ball carrier, it was considered a double tackle.
Group tackles	The total number of group tackles that occurred. A group tackle was when a tackle was completed by three or more players, all of whom notably contributed to the grounding of the ball carrier.
Missed tackles	The total number of missed tackles that occurred. A missed tackle was when one or more opposing players made contact with the ball carrier and failed to bring him to ground.

Line breaks	The total number of line breaks that occurred. When a player broke through the opponents' defensive line without being tackled, it was considered a line break.

STATISTICAL ANALYSIS

The statistical data processing package (Statsoft Inc., 2011) was used to process the data. Descriptive statistics (means and standard deviations) were reported and a significance level of 5% ($p < 0.05$) was used as guideline for determining significant differences. Mixed-model repeated-measures ANOVA was used to compare halves of the match and years, with halves treated as within subjects fixed factor and year as between subjects fixed factor. The matches analysed (nested in year) were treated as random effect. Spearman correlation coefficient was used to determine the reliability. Intra-rater agreement were interpreted as follows: poor (0.0.20), fair (0.30-0.40), moderate (0.50-0.60), strong (0.70-0.80), and almost perfect (>0.80). Analysis showed that each variable revealed an almost perfect agreement.

3.3 RESULTS

The results will be discussed under the following headings: *scoring profile, time interval profile, general skills profile and contact profile*.

SCORING PROFILE

The results for the scoring profile, displayed in Tables 3.2 and 3.6, indicated that the *total points scored* between the seasons did not show any significant change (26.1 ± 11.7 vs 25.7 ± 9.6, $p = 0.81$); however, the source of points scored changed from tries to penalty kicks. The total number of *tries scored* showed a decreasing trend from 2007 to 2013 ($p = 0.07$), particularly in the 2nd half of the match in 2013 ($p = 0.05$). There were no significant differences between the source of the tries (scrum $p = 0.13$, line-out $p = 0.25$, open play $p = 0.26$). The decrease in tries consequently led to a decrease in the number of *conversion kicks* ($p = 0.07$).

The main source of points was *penalty kicks*, which showed a significant increase from 2007 to 2013 (2.3 ± 1.8 vs 3.5 ± 1.9, $p < 0.01$). The accuracy of the *penalty kicks* also changed, with the success of penalty kicks increasing significantly (1.4 ± 1.3 vs 2.6 ± 1.5, $p < 0.01$). The success of *penalty goals* therefore increased from 63% in 2007 to 75% in 2013.

TIME INTERVAL PROFILE

The time interval results revealed that the number of *stoppages* in matches decreased significantly from 2007 to 2013 (41.4 ± 5.9 vs 36.6 ± 5, $p < 0.01$) (Tables 3.3 and 3.7). The number of *injuries* showed no significant differences ($p = 0.27$); however, when comparing the halves, there was a significant increase in the number of *injuries* in the 2nd half of the match of both years (2007, $p = 0.03$ and 2013, $p = 0.04$). The number of *replacements/substitutes* introduced to the game showed no significant change ($p = 0.96$); however, there was a significant increase in the number of *replacements/substitutes* introduced in the 2nd half of the match in both years (2007, $p < 0.01$ and 2013, $p < 0.01$) as seen in Table 3.7.

GENERAL SKILLS PROFILE

The general skills profile indicated that the number of *passes completed* increased from 2007 to 2013 (104.8 ± 19.6 vs 113.6 ± 24.7, $p = 0.04$) (Tables 3.4 and 3.8). When comparing the halves of matches, there was a significant increase in the number of *passes completed* in the 2nd half for both years (2007, $p < 0.01$ and 2013, $p < 0.01$) as seen in Table 3.8. The number of *handling errors* showed a significant decrease from 2007 to 2013 (19.7 ± 5.4 vs 16.3 ± 4.5, $p < 0.01$), while the number of *offloads* during tackles also revealed a significant decrease from 2007 to 2013 (12.3 ± 5.4 vs 7.3 ± 4.0, $p < 0.01$) and the number of *kicks* performed decreased significantly between 2007 and 2013 (29.7 ± 8 vs 24.6 ± 8.6, $p < 0.01$).

Table 3.2 Scoring profile descriptive statistics for the 2007 and 2013 seasons

Scoring profile PI	2007 *n* = 74	2013 *n* = 66	p-value$_1$	p-value$_2$	r-value
Total points scored	26.1 ± 11.7	25.7 ± 9.6	0.81	0.90	**1.00**
Tries scored	**3.3 ± 2.0**	**2.7 ± 1.5**	**0.07****	0.88	**1.00**
Source - Scrum	0.6 ± 0.8	0.4 ± 0.6	0.13	0.21	**1.00**
Source - Line-out	1.1 ± 1.1	0.9 ± 0.9	0.25	0.10	**1.00**
Source - Open play	1.6 ± 1.3	1.3 ± 1.1	0.26	0.73	**1.00**
Conversion kicks	3.3 ± 2.0	2.6 ± 1.5	**0.07****	0.97	**1.00**
Successful	2.3 ± 1.6	1.9 ± 1.4	0.16	0.71	**1.00**
Missed	**1 ± 1**	**0.7 ± 0.8**	**0.07****	0.45	**1.00**
Penalty kicks	**2.3 ± 1.8**	**3.5 ± 1.9**	**<0.01***	0.91	**1.00**
Successful	**1.4 ± 1.3**	**2.6 ± 1.5**	**<0.01***	0.99	**1.00**
Missed	0.8 ± 1	0.8 ± 1	0.83	0.99	**1.00**
Drop kicks	0.4 ± 0.8	0.3 ± 0.7	0.51	0.63	**1.00**
Successful	0.1 ± 0.4	0.1 ± 0.4	0.67	0.43	**1.00**
Missed	0.3 ± 0.6	0.2 ± 0.5	0.56	0.93	**1.00**

*Note: p-value$_1$: differences between the 2007 and 2013 seasons; p-value$_2$: interaction effect between the 1st and 2nd halves of the match during the 2007 and 2013 seasons; * = statistically significant difference between the 2007 and 2013 seasons; ** = a trend towards a statistically significant difference between the 2007 and 2013 seasons; r-value: reliability correlation coefficient.*

Table 3.3 Time interval profile descriptive statistics for the 2007 and 2013 season

Time interval profile PI	2007 *n* = 74	2013 *n* = 66	p-value$_1$	p-value$_2$	r-value
Stoppages	**41.4 ± 5.9**	**36.6 ± 5**	**<0.01***	0.62	0.99
Injuries	5 ± 2.5	4.5 ± 2.3	0.27	0.99	**1.00**
Replacements/Substitutes	6.1 ± 5	6.1 ± 4.6	0.96	**0.03***	**1.00**

*Note: p-value$_1$: differences between the 2007 and 2013 seasons; p-value$_2$: interaction effect between the 1st and 2nd halves of the match during the 2007 and 2013 seasons; * = statistically significant difference between the 2007 and 2013 seasons; ** = a trend towards a statistically significant difference between the 2007 and 2013 seasons; r-value: reliability correlation coefficient.*

Table 3.4 General skills profile descriptive statistics for the 2007 and 2013 season

General skills profile PI	2007 *n* = 74	2013 *n* = 66	p-value$_1$	p-value$_2$	r-value
Passes completed	**104.8 ± 19.6**	**113.6 ± 24.7**	**0.04***	**0.67**	0.99
Handling errors	**19.7 ± 5.4**	**16.3 ± 4.5**	**<0.01***	**0.41**	0.96
Offloads in the tackle	**12.3 ± 5.4**	**7.3 ± 4.0**	**<0.01***	**0.03***	0.98
Kicks	**29.7 ± 8**	**24.6 ± 8.6**	**<0.01***	**0.07****	0.99

*Note: p-value$_1$: differences between the 2007 and 2013 seasons; p-value$_2$: interaction effect between the 1st and 2nd halves of the match during the 2007 and 2013 seasons; * = statistically significant difference between the 2007 and 2013 seasons; ** = a trend towards a statistically significant difference between the 2007 and 2013 seasons; r-value: reliability correlation coefficient.*

CONTACT PROFILE

Tables 3.5 and 3.9 indicate that the total number of *rucks/mauls* increased significantly from 2007 to 2013 (68.9 ± 12.9 vs 84.3 ± 16.1, $p < 0.01$), with the total number of balls retained increasing (61.8 ± 11.7 vs 80 ± 15.7, $p < 0.01$) and the total number of turnovers decreasing (7 ± 3 vs 4.5 ± 2.2, $p < 0.01$). The success rate of *rucks/mauls* therefore increased from 90% in 2007 to 95% in 2013. When comparing the halves of the match, there was a significant increase in the number of *rucks/mauls* in the 2nd halves of both years ($p < 0.01$).

The number of *scrums* decreased significantly from 2007 to 2013 (9.3 ± 3 vs 6.9 ± 2.4, $p < 0.01$), with the number of *scrums won, lost and reset* all decreasing, as seen in Table 3.5. The success of *scrums* for the attacking team decreased from 89% in 2007 to 86% in 2013. The number of *line-outs* also showed a significant decrease from 2007 to 2013 (15.6 ± 3.3 vs 12.3 ± 3.1, $p < 0.01$), with the number of *line-outs won* and *lost* both decreasing, as seen in Table 3.5. The success of *line-outs* for the attacking team increased from 75% in 2007 to 85% in 2013.

The number of *successful tackles* completed showed a significant increase from 2007 to 2013 (72.6 ± 14.6 vs 94.2 ± 17.8, $p < 0.01$), with *single* and *double tackles* showing the largest increase, as seen in Table 3.5. When comparing the halves of the match, there

was a significant increase in the number of *successful tackles* (*single* and *double tackles*) in the 2nd half of both years ($p < 0.01$). The number of *missed tackles* showed no significant change between the seasons ($p = 0.46$). The success rate of *tackles* improved from 74% in 2007 to 78% in 2013, with *single tackles* being the predominant type of tackle. The results of the number of *line breaks* decreased significantly from 2007 to 2013 (6.6 ± 2.7 vs 2.8 ± 2, $p < 0.01$).

Table 3.5 Contact profile descriptive statistics for the 2007 and 2013 seasons

Contact profile PI	2007 *n* = 74	2013 *n* = 66	p-value$_1$	p-value$_2$	r-value
Rucks/Mauls	**68.9 ± 12.9**	**84.3 ± 16.1**	**<0.01***	0.50	0.99
Won	**61.8 ± 11.7**	**80 ± 15.7**	**<0.01***	0.39	0.99
Lost	**7 ± 3**	**4.5 ± 2.2**	**<0.01***	0.31	0.99
Scrums	**9.3 ± 3**	**6.9 ± 2.4**	**<0.01***	0.25	**1.00**
Won	**8.8 ± 2.9**	**5.8 ± 2.4**	**<0.01***	0.21	**1.00**
Lost	**0.5 ± 0.7**	**1.1 ± 1.2**	**<0.01***	0.76	**1.00**
Scrum resets	**3.4 ± 2.3**	**1.9 ± 1.4**	**<0.01***	0.81	**1.00**
Line-outs	**15.6 ± 3.3**	**12.3 ± 3.1**	**<0.01***	0.33	**1.00**
Won	**13.3 ± 3.3**	**10.7 ± 2.9**	**<0.01***	0.29	**1.00**
Lost	**2.2 ± 1.5**	**1.7 ± 1.3**	**0.03***	0.92	**1.00**
Successful tackles	**72.6 ± 14.6**	**94.2 ± 17.8**	**<0.01***	0.46	0.99
Single	**36.5 ± 8**	**49 ± 10.9**	**<0.01***	0.47	0.99
Double	**30 ± 8.5**	**40 ± 9.1**	**<0.01***	0.51	0.98
Group	6 ± 3.1	5.3 ± 2.7	0.19	0.80	0.94
Missed tackles	24.9 ± 8.2	26 ± 7.1	0.46	0.13	0.90
Line breaks	**6.6 ± 2.7**	**2.8 ± 2**	**<0.01***	0.23	0.99

*Note: p-value$_1$: differences between the 2007 and 2013 seasons; p-value$_2$: interaction effect between the 1st and 2nd halves of the match during the 2007 and 2013 seasons; * = statistically significant difference between the 2007 and 2013 seasons; ** = a trend towards a statistically significant difference between the 2007 and 2013 seasons; r-value: reliability correlation coefficient.*

Table 3.6 Scoring profile descriptive statistics for the 1st and 2nd halves of matches for the 2007 and 2013 seasons

Scoring Profile PI	2007 1st Half *n* = 37	2007 2nd Half *n* = 37	2013 1st Half *n* = 33	2013 2nd Half *n* = 33	2007 1st & 2nd Half p-value$_1$	2013 1st & 2nd Half p-value$_2$	2007 vs. 2013 1st Halves p-value$_3$	2007 vs. 2013 2nd Halves p-value$_4$
Total points scored	25.9 ± 10.9	26.4 ± 12.6	25.6 ± 8.4	25.7 ± 10.7				
Tries scored	3.1 ± 1.9	3.5 ± 2	2.4 ± 1.2	2.9 ± 1.8				**0.05****
Source – Scrum	0.5 ± 0.7	0.7 ± 0.8	0.5 ± 0.6	0.4 ± 0.7				
Source – Line-out	1.3 ± 1.3	0.9 ± 0.9	0.8 ± 0.8	0.9 ± 1	**0.04**		**0.05****	
Source – Open play	1.3 ± 1.1	1.9 ± 1.5	1.1 ± 0.8	1.5 ± 1.3	**0.02**			
Conversion kicks	3.3 ± 1.9	3.5 ± 2	2.4 ± 1.2	2.8 ± 1.8				
Successful	2 ± 1.4	2.6 ± 1.7	1.7 ± 1	2.1 ± 1.7	**0.06****			
Missed	1.1 ± 1.1	0.9 ± 0.9	0.7 ± 0.8	0.7 ± 0.7			**0.07****	
Penalty kicks	**2.9 ± 1.8**	**1.6 ± 1.6**	**4.2 ± 1.9**	**2.8 ± 1.8**	**<0.01**	**<0.01**	**<0.01**	**<0.01**
Successful	**1.8 ± 1.4**	**1.1 ± 1.2**	**3 ± 1.6**	**2.2 ± 1.4**	**<0.01**	**<0.01**	**<0.01**	**<0.01**
Missed	**1 ± 1**	**0.6 ± 0.9**	**1.1 ± 1**	**0.6 ± 0.9**	**0.04**	**0.05****		
Drop kicks	0.5 ± 0.8	0.4 ± 0.8	0.5 ± 0.8	0.2 ± 0.5				
Successful	0.2 ± 0.4	0.1 ± 0.3	0.2 ± 0.5	0.1 ± 0.2				
Missed	0.4 ± 0.6	0.2 ± 0.5	0.3 ± 0.6	0.2 ± 0.4				

*Note: p-value$_1$: differences between the 1st and 2nd halves of the match during the 2007 season; p-value$_2$: differences between the 1st and 2nd halves of the match during the 2013 season; p-value$_3$: differences between the 1st halves of the match during the 2007 and 2013 seasons; p-value$_4$: differences between the 2nd halves of the match during the 2007 and 2013 seasons; * = statistically significant difference between the 2007 and 2013 seasons; ** = a trend towards a statistically significant difference between the 2007 and 2013 seasons.*

Table 3.7 Time interval profile descriptive statistics for the 1st and 2nd halves of matches for the 2007 and 2013 seasons

Time interval PI	2007		2013		2007	2013	2007 vs 2013	2007 vs 2013
	1st Half	2nd Half	1st Half	2nd Half	1st & 2nd Half	1st & 2nd Half	1st Halves	2nd Halves
	n = 37	*n* = 37	*n* = 33	*n* = 33	p-value$_1$	p-value$_2$	p-value$_3$	p-value$_4$
Stoppages	**40.8 ± 6.2**	**42.1 ± 5.6**	**36.4 ± 4.7**	**36.9 ± 5.4**			**<0.01***	**<0.01***
Injuries	**4.5 ± 2**	**5.5 ± 2.9**	**4 ± 1.9**	**5.1 ± 2.5**	**0.03***	**0.04***		
Replacements/Substitutes	**1.4 ± 1.2**	**10.9 ± 1.8**	**2 ± 1.3**	**10.2 ± 2.4**	**<0.01***	**<0.01***		

*Note: p-value$_1$: differences between the 1st and 2nd halves of the match during the 2007 season; p-value$_2$: differences between the 1st and 2nd halves of the match during the 2013 season; p-value$_3$: differences between the 1st halves of the match during the 2007 and 2013 seasons; p-value$_4$: differences between the 2nd halves of the match during the 2007 and 2013 seasons; * = statistically significant difference between the 2007 and 2013 seasons; ** = a trend towards a statistically significant difference between the 2007 and 2013 seasons.*

Table 3.8 Skills profile descriptive statistics for the 1st and 2nd halves of matches for the 2007 and 2013 seasons

Skills PI	2007		2013		2007	2013	2007 vs 2013	2007 vs 2013
	1st Half	2nd Half	1st Half	2nd Half	1st & 2nd Half	1st & 2nd Half	1st Halves	2nd Halves
	n = 37	*n* = 37	*n* = 33	*n* = 33	p-value$_1$	p-value$_2$	p-value$_3$	p-value$_4$
Passes completed	**97.3 ± 15.4**	**112.4 ± 20.5**	**107.2 ± 22.4**	**119.9 ± 25.6**	**<0.01***	**<0.01***	**0.05****	
Handling errors	**18.8 ± 5.2**	**20.5 ± 5.6**	**16 ± 4.6**	**16.5 ± 4.6**			**0.02***	**<0.01***
Offloads in the tackle	**10.3 ± 4.3**	**14.2 ± 5.8**	**7 ± 3**	**7.6 ± 4.9**	**<0.01***		**<0.01***	**<0.01***
Kicks	**31.4 ± 7.6**	**28.1 ± 8.1**	**24.2 ± 7.2**	**25 ± 9.8**	**0.03***		**<0.01***	

*Note: p-value$_1$: differences between the 1st and 2nd halves of the match during the 2007 season; p-value$_2$: differences between the 1st and 2nd halves of the match during the 2013 season; p-value$_3$: differences between the 1st halves of the match during the 2007 and 2013 seasons; p-value$_4$: differences between the 2nd halves of the match during the 2007 and 2013 seasons; * = statistically significant difference between the 2007 and 2013 seasons; ** = a trend towards a statistically significant difference between the 2007 and 2013 seasons.*

Table 3.9 Contact profile descriptive statistics for the 1st and 2nd halves of matches for the 2007 and 2013 seasons

Contact profile PI	2007 1st Half *n* = 37	2007 2nd Half *n* = 37	2013 1st Half *n* = 33	2013 2nd Half *n* = 33	2007 1st & 2nd Half p-value$_1$	2013 1st & 2nd Half p-value$_2$	2007 vs 2013 1st Halves p-value$_3$	2007 vs 2013 2nd Halves p-value$_4$
Rucks/Mauls	**65.2 ± 11.2**	**72.5 ± 13.6**	**79.2 ± 14.6**	**89.5 ± 16.2**	**0.02***	**<0.01***	**<0.01***	**<0.01***
Won	**58.9 ± 10.8**	**64.6 ± 12**	**75.4 ± 14.3**	**84.7 ± 15.8**	**0.05****	**<0.01***	**<0.01***	**<0.01***
Lost	**6.3 ± 2.3**	**7.6 ± 3.5**	**4.2 ± 2**	**4.7 ± 2.3**	**<0.01***		**<0.01***	**<0.01***
Scrums	**8.8 ± 3**	**9.9 ± 2.9**	**6.8 ± 2.1**	**6.9 ± 2.8**			**<0.01***	**<0.01***
Won	**8.3 ± 3**	**9.4 ± 2.9**	**5.8 ± 2.3**	**5.8 ± 2.4**			**<0.01***	**<0.01***
Lost	**0.5 ± 0.7**	**0.5 ± 0.7**	**1 ± 1.1**	**1.2 ± 1.2**			**0.02***	**<0.01***
Scrum resets	**3.5 ± 2.4**	**3.4 ± 2.2**	**2 ± 1.5**	**1.8 ± 1.4**			**<0.01***	**<0.01***
Line-outs	**15.9 ± 3.1**	**15.3 ± 3.5**	**12.1 ± 3**	**12.6 ± 3.1**			**<0.01***	**<0.01***
Won	**13.8 ± 3**	**12.9 ± 2.4**	**10.6 ± 3.1**	**10.8 ± 2.8**			**<0.01***	**<0.01***
Lost	**2.1 ± 1.5**	**2.4 ± 1.5**	**1.5 ± 1.4**	**1.8 ± 1.3**				
Tackles	**68.6 ± 13.4**	**76.6 ± 14.7**	**88.5 ± 15.3**	**100 ± 18.5**	**<0.01***	**<0.01***	**<0.01***	**<0.01***
Single	**34.5 ± 7.1**	**38.6 ± 8.3**	**45.8 ± 10.1**	**52.2 ± 11**	**0.04****	**<0.01***	**<0.01***	**<0.01***
Double	**28.4 ± 8.7**	**31.7 ± 8.1**	**37.5 ± 7.9**	**42.5 ± 9.6**	**0.06****	**<0.01***	**<0.01***	**<0.01***
Group	**5.8 ± 2.7**	**6.2 ± 3.4**	**5.2 ± 2.5**	**5.4 ± 2.9**				
Missed tackles	**22.9 ± 7.7**	**26.8 ± 8.4**	**25.7 ± 7**	**26.3 ± 7.3**	**<0.01***			
Line breaks	**6.3 ± 2.1**	**6.9 ± 3.2**	**2.9 ± 2.1**	**2.7 ± 1.9**			**<0.01***	**<0.01***

*Note: p-value$_1$: differences between the 1st and 2nd halves of the match during the 2007 season; p-value$_2$: differences between the 1st and 2nd halves of the match during the 2013 season; p-value$_3$: differences between the 1st halves of the match during the 2007 and 2013 seasons; p-value$_4$: differences between the 2nd halves of the match during the 2007 and 2013 seasons; * = statistically significant difference between the 2007 and 2013 seasons; ** = a trend towards a statistically significant difference between the 2007 and 2013 seasons.*

3.4 DISCUSSION

The aim of this study was to compare the 2007 and 2013 seasons of the South African Currie Cup tournament in order to determine the effect of the law changes on the scoring, time interval, general skills and contact profiles. The study also underlined the importance of analysing rugby matches as 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 only been contributed by a change in one half and not the other. Table 3.10 provides a summary of the law changes and the possible effects thereof on the match profile.

Table 3.10 Summary of the law changes and the effect thereof on the game

Law change	Description	Effect
Law 16.7 (c) : Unsuccessful end to a ruck	When the ball has been clearly won by a team at a ruck and is available to be played the referee will call "use it", after which the ball must be played within five seconds. If the ball is not played within the five seconds the referee will award a scrum and the team not in possession of the ball at the ruck will be awarded the throw-in.	Increased the number of passes, tackles and rucks, which in turn reduced the number of line breaks and tries scored.
Law 19.2: Quick throw-in	For a quick throw-in, the player may be anywhere outside the field of play between the line of touch and the player's goal line.	Reduced the number of kicks and line-outs.

Law 20.1 (g): Forming a scrum	The referee will call “crouch” then “touch”. The front rows crouch and, using their outside arm, each prop touches the point of the opposing prop’s outside shoulder. The props then withdraw their arms. The referee will then call “set” when the front rows are ready. The front rows may then engage. The “set” call is not a command but an indication that the front rows may come together when ready.	Reduced the number of scrum resets and the number of stoppages.

The results of the scoring profile, displayed in Tables 3.2 and 3.6, show that the *total points scored* between the seasons had not changed significantly; however, the source of points had changed from tries to penalty kicks. The *number of tries* scored showed a decreasing trend while the *number of penalty kicks*, and the success thereof, increased significantly. The decreasing tendency to score tries and kick penalty goals was seen in the Rugby Championship, Six Nations championship and Japanese top league [14, 15, 16].

The possible cause of the reduction in tries could be the introduction of **Law 16.7 (c), unsuccessful end to a ruck, which states that when the ball has been clearly won by a team at a ruck and is available to be played the referee will call "use it", after which the ball must be played within five seconds.** The law change may have led teams to adopt a more defensive strategy, whereby they may be sacrificing the possibility of winning turnovers at the breakdown by committing more players to defensive tackle situations to favour more numbers on defence [17]. This strategy is supported by the significant increase in game actions (passing, tackles and rucks/mauls) and the decrease in *line breaks* seen in Tables 3.5 and 3.9. These results also follow a pattern similar to that identified by Laird and Lorimer [18] when they

reviewed the game and compared the findings to previous statistically analysed studies. They found a significant correlation between the number of passes completed and tackles to the number of tries and concluded that the more passes and tackles made in a phase of play, the less chance there is for a try to be scored. Diedrick and Van Rooyen [19] analysed the events leading up to scoring a try in international rugby and found that 51% of tries scored resulted from a line break. With the continuous development of rugby and the increasing competitiveness of the game, there has been an increased emphasis on analysing and training specific areas of the game, which has led to the introduction of specialist coaches who focus on interpreting and developing those specific areas [2]. A possible cause of the current scoring trend could also be the introduction of these specialist coaches (defensive and kicking coaches) in professional structures [16], which may have promoted the increased success of kicking and ball retention at rucks/mauls, as seen in Tables 3.4 and 3.5. Therefore, the introduction of **Law 16.7 (c)** and specialist coaches may have led teams to adopt a more defensive approach, with teams struggling to penetrate the defence and finding themselves passing and being tackled more frequently, thereby increasing the difficulty to score points. Whether players and spectators will find physical, closely contested battles with fewer tries enjoyable or entertaining (principles of the laws in the IRB charter) is debatable [14].

The time interval profile results revealed that the *number of stoppages* to the game has decreased significantly. The introduction of **Law 20.1 (g), new formation of a scrum**, may have played the biggest role in reducing the *number of stoppages* as the *number of scrum resets* has decreased significantly. With the decrease in *handling errors*, leading to fewer *scrums*, and the decrease in *kicks*, leading to fewer *line-outs*, the decisions taken on the field are dictating a more continuous game. The increased number of game actions (passing, tackles and rucks/mauls), caused by the introduction of **Law 16.7 (c), led to an** increased *number of injuries* and a decrease in the *number of stoppages*, which would suggest that the intensity and continuity of the game have increased, predominantly in the second halves; however, the significant increase in the *number of replacements/substitutes* introduced in the 2nd half, as seen in Table 3.3, could be one of the reasons for the increased activity. These findings support previous studies that suggested that the profile of matches would become faster paced and more ruck-dominated contests [11, 20]. Therefore, the introduction

of **Law 20.1 (g)** has reduced the *number of scrum resets* and the *number of stoppages* to the match. The introduction of **Law 16.7 (c),** which as mentioned previously increased the number of game actions (passing, tackles, rucks/mauls), may have promoted an increase in the *number of injuries*.

The general skills profile results, displayed in Tables 3.4 and 3.8, show a significant increase in the *number of successful passes completed* and a significant decrease in the *number of handling errors*. With the increased proficiency in defence, resulting from the introduction of **Law 16.7 (c)**, teams may be opting to pass the ball over shorter distances and set up more rucks in an attempt to draw as many opponents into the breakdown situation as possible in order to create an overlap on the wings. This tactic would increase the *number of passes and rucks* and also increase the possibility of conceding a penalty, which could result in a penalty kick for points. The reduced *number of offloads* during the tackle indicates that players may be choosing a safer option of maintaining possession and gaining territory by driving forward in the tackle and attempting to gain as much ground as possible, rather than attempting to offload the ball to a supporting player who has a chance to knock the ball forward (increasing the handling errors) and losing possession. The increase in the *number of double tackles* (2 vs. 1 situation) may also have contributed to the decline in the *number of offloads*, as the ball carrier does not have enough time or is limited in physical movement to offload the ball. The *number of kicks* has also shown a decline. This may be due to the introduction of **Law 19.2, quick throw-ins may be anywhere outside the field of play between the line of touch and the player's goal line.** With the increased range of a quick throw-in, when kicking to gain territory, teams may find they are not gaining a large amount of territory from the kick as the opposing teams are counter-attacking from a quick throw-in further towards the line of touch instead of resorting to a line-out where the ball went out. Teams may now only resort to kicking the ball when put under pressure close to their try line and favour maintaining possession rather than risk losing it by kicking when approaching defending opponents. This further supports the notion that teams would rather resort to physically progressing up the field than kicking and possibly losing possession. Therefore the introduction of **Law 16.7 (c)** may have increased the *number of passes completed* and the introduction of **Law 19.2** may have reduced the *number of kicks* and *line-outs*.

The contact profile, displayed in Tables 3.5 and 3.9, revealed a significant increase in the *number of rucks/mauls* formed and an increase in the *number of rucks/mauls* won by the attacking team, from 90% in 2007 to 95% in 2013. The high level of ball retention at the breakdown (91%) was also seen across the whole 2007 Rugby World Cup tournament. Van Rooyen *et al.* [20] and Jones *et al.* [12] also found an average ruck success rate of 91%, with winning teams' success rate being 93% and losing teams' success rate 90.5%. The increased success at the breakdowns could be a result of the introduction of **Law 16.7 (c)**, which may have led defending teams to commit more players to defence than to the breakdown as teams may be recycling the ball quicker. This may also have influenced the decrease in the *number of line breaks*, as there are more players on defence and limited space for players to move. Van Rooyen *et al.* [20] evaluated ruck frequency as a predictor of success in the 2007 Rugby World Cup and found that during the knockout stage matches, more rucks were formed and fewer points scored compared to the pool stage matches. This indicated an increase in the physical activity of the matches and the difficulty to score points. These findings are similar to those of this study, as the *number of rucks* has increased and the *number of tries scored* has decreased, resulting in a more physically intense match. With the focus having shifted towards defensive tackling situations, teams may be trying to gain possession before a ruck is formed, which may have resulted in the number of double tackles having increased. Teams may be attempting to dominate the tackle situation rather than trying to dominate the breakdowns in order to gain possession and apply defensive pressure [21]. Therefore the introduction of **Law 16.7 (c)** may have increased the *number of rucks* and *tackles* and led teams to dominate the tackle situations rather than the breakdowns.

The changes in the profile of the competition cannot just be due to law changes as addressed by the study. There are other factors that could have contributed to the change in physical profile: a) the growth of player's physical attributes. During the period players, both currently in the senior team and younger, developing players, may have become stronger, faster and more skilful thereby, possibly, making it more difficult to tackle or chase. The emphasis placed on long-term athletic development has ensured that players receive structured training for future elite performances [22, 23]; b) the introduction of new coaching staff. New coaches and trainers would implement new structures and training protocols in order to change the teams play

style, which in turn would change the players physically. Opposing teams would then have to adapt their current tactics to gain the competitive edge, this would therefore change the profile of the match compared to previous encounters with the old coached play style; c) the length of the Super Rugby competition (competition before the Currie Cup) and the success of the South African teams in the competition may affect the intensity of the matches in the Currie Cup tournament. The expansion of the Super Rugby competition in 2011 may have placed additional physical demands on the teams, particularly to those South African teams that excel to the final. Once the quarter final matches have been decided teams which have not qualified will start preparations for the Currie Cup tournament. South African teams that progress to the final rounds delay their preparations for the Currie Cup. The final play-off matches increase the volume of high-intensity activities and increase the possibility of injury to players [24]. These factors could contribute to selecting alternate players or the intensity of Currie Cup matches decreasing due to fatigue; d) the format of the tournament changing. The format of the tournament changed in 2012, from 8 teams participating (five franchise unions, that participate in the Super Rugby competition, and three qualifying team) to 6 teams (five super rugby franchise unions and one qualifying team). Due to the structuring of the tournament, the teams participating may be of equal strengths, therefore creating more closely contested matches which are physically intense. This would suggest the main source of points being penalty kick rather than tries as the improved defensive structure reduces the opportunity of tries to be scored; e) The return of the springbok players from international duty and their inclusion late in the season (final pool rounds, semi-final and final matches), may have had an impact on various aspects of the match. These players are considered the most skilful players in the country and may possibly impact the outcome of matches, particularly to those teams which have more than one springbok in which they integrate into the team. International players experience higher physical demands during international matches than when they play at lower levels and are conditioned to meet the greater match demands of international rugby [25]. Therefore, experienced international players would be able to easily handle the demands of domestic matches and would also be able to player at a higher intensity compared to other players who have not experienced international rugby [25];

PRACTICAL APPLICATIONS

Based on the effect of the law changes on the match profile, shown in Table 3.10, the next section will recommend practical applications to coaches and trainers to assist with the development of rugby-specific training programmes.

MONITORING

The norm for technical staff is to analyse and record match data as a whole match, but in order to be more specific one could break the match down into two separate halves, as some significant information may be lost when adding the two halves together,. For example, one half's PIs may be significantly higher than the other half. Profiles for tournaments and opponents should be developed to help understand what players go through physically and help understand and interpret tactical strengths and weaknesses. Research on muscle damage and recovery among rugby players during matches has shown that the degree of muscle damage was related to the number of contacts sustained in a match [26, 27, 28]. Analysts could identify the number of contact situations each player is involved in, which coaches, trainers and medical staff could use when monitoring players, implementing recovery strategies and planning training loads.

SKILLS COACHING

Skill-oriented sessions, goal kicking in particular, should be a priority in training schedules and should focus on developing players' technical mastery of the skill, as well as developing it in pressure situations. Before training sessions, the kickers of teams should focus on specific warm-up and muscle activation exercises that focus on hip and knee mobility and stability during normal and single-leg stance and lower leg limb cadence.

CONDITIONING OF PLAYERS AND TEAMS

When looking at speed and agility or interval training, training programmes should put emphasis on developing players around the various contact situations in the game and not only the running-based demands. This must be of high importance for developing effective forwards, as they participate in the most contact situations during a match [27]. Repeated sprint sessions should include short periods of resistance work

between the sets and/or repetitions. Gabbett [28] analysed the sprint patterns of national rugby league players and found that 48% of sprints end in a collision. The most recent development in training drill is the Rugby-specific Repeated Sprint (RS^2), which simulates the repeated running and contact efforts of the game [29]. Adding intermittent wrestling to small-sided games has been found to improve the repeated high-intensity effort ability specific to rugby, as well as introduce a level of pressure and fatigue. Importantly, the addition of wrestling has been shown not to compromise the volume or quality of skill involvement; instead, players adapt to the constraints by producing faster ball movements [30].

Agility training involving contact could be incorporated into current speed and contact drills. Wheeler and Sayers [21] examined the running technique of rugby players during various conditions and found that players changed their running technique in response to a defender. They highlighted the importance of body height and shortening strides to fend off defenders. Worsnop [31] also mentioned key aspects of dominating contact for both attacking and defending players. High levels of leg strength are needed to drive forward in the contact and upper body strength to twist and turn the ball carrier. Training these techniques, of dominating contact, could prevent excessive body impact and associated injuries [26, 27]. Training sessions that target specific energy systems should not only focus on repeated running movements (accelerating, decelerating) but also include falling down and getting back up, as these movements follow tackles and rucks/mauls. The energy expenditure of falling and getting back up is demanding on players. Multi-direction movements should be implemented into speed training sessions and warm-up plans, as these movements are prominent when players are forming defensive patterns. Backward running and side shuffling, when players are placing themselves on defence, followed by forward movements, stepping forward or jogging should also be included. When designing fitness sessions based on defensive patterns these movements should be used to tire players. Preseason rugby training should place a priority on strength development and transferring strength to functional, rugby-specific movements. The use of plyometrics and strongman-based strength/power exercises is ideal for transferring strength gains attained into functional, more specific movements [32].

3.5 CONCLUSION

In conclusion, the study firstly revealed that the profile of the game has changed to one that is more physical and continuous, with an increased number of player actions (passing, tackling and rucks/mauls) and a reduced number of stoppages, predominantly in the second half. Secondly, a trend revealed that teams are adopting a more defensive playing style, whereby they sacrifice committing numbers to the breakdowns and rather commit players on defence. This has created a more physically intense match with fewer tries being scored. The results from this study emphasise the importance of further research into match and tournament profiles and identifying tactical and physical trends. Future studies should focus on identifying the physical profile of the under 19 and under 21 Currie Cup tournaments and comparing the differences between the different levels. This could lead to improvements in training regimes and programmes by preparing players for the specific demands of the tournament. Studies should also focus on analysing the changes in the English, European and New Zealand domestic competitions and determining whether there are differences between the nations' domestic competitions.

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CHAPTER FOUR

RESEARCH ARTICLE TWO:

THE EFFECT OF THE LAW CHANGES ON TIME VARIABLES OF THE SOUTH AFRICAN CURRIE CUP TOURNAMENT DURING 2007 AND 2013

This chapter is included herewith in accordance with the guidelines of the International Journal of Performance Analysis in Sport (Appendix A).

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The effect of the law changes on time variables of the South African Currie Cup Tournament during 2007 and 2013

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The effect of the law changes on time variables of the South African Currie Cup Tournament during 2007 and 2013

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Abstract

In rugby, several law changes and/or amendments have been introduced between 2007 and 2013, yet the impact of these changes has not yet been objectively evaluated. Therefore the aim of this study was to determine the impact of the law changes and amendments on the time intervals and contact profile of the South African Currie Cup Tournament during the 2007 and 2013 seasons. A total 70 matches were analysed using Dartfish video analysis software. The frequencies of 15 performance indicators were used for the aim of this study. The time interval profiles revealed that the total match time and total stoppage time increased significantly ($p < 0.01$), while the total ball in play time decreased significantly ($p < 0.01$). The individual phase activity also indicated a significant decrease $p < 0.01$). The contact profile revealed that the total tackle time increased significantly ($p < 0.01$), while the total ruck/maul-, scrum- and line-out- times decreased significantly ($p < 0.01$). The study revealed that the profile of the South African game has become more continuous, with total time spent at rucks/mauls and between subsequent rucks decreasing. The findings of this study can assist coaches and trainers with information to re-create match situations during training in order to improve performance during match play.

Key words: Performance indicators, law changes, performance analysis, time variables

4.1 Introduction

The profile of sport is constantly changing and the game of rugby union (rugby) is frequently pushed to the limit both by the players and coaches (Eaves *et al.*, 2008). Professionalism in rugby has led to changes in players' fitness profiles. Players have become faster, stronger, more powerful and clinical in implementing these physical attributes within the laws of the game (Smart *et al.*, 2013; Austin *et al.*, 2011; Kraak *et al.*, 2011; Duthie *et al.*, 2003). Professionalism in rugby has resulted in the need for improved scientific and analytic support aimed at maximising performance (Vaz *et al*., 2011). As a result, the science of examining the sport and players' performance has grown to meet the increasing demands for knowledge on game tactics and player demands (Duthie *et al.*, 2003). With the continuous development of rugby and the increasing competitiveness of the game, there has been an increased emphasis on the use of technology and scientific support to aid trainers and coaches to maximise performance (Bishop & Barnes, 2013; James *et al.*, 2005). Recently, the use of performance analysis, more specifically notational analysis/match analysis, has shown noticeable growth, as this tool provides trainers and coaches with detailed analysis of the performances of individuals and teams (Wright *et al*., 2012).

As stated earlier, the profile of rugby is constantly changing with the introduction of new technology and law changes and/or amendments (Van den Berg & Malan, 2012; Eaves *et al.*, 2008). Many of the law changes have been introduced and implemented to increase the continuity and competitiveness of the game, especially during the periods 2007 and 2013. With the added use of technology, coaches and trainers can scrutinise player activities and match play (Eaves *et al.*, 2008). Evaluating the effects of these law changes and match profiles has primarily focused on technical and tactical aspects of the game and very little on the physical profile and its implications for the training and conditioning of players and teams (Wright *et al*., 2012; O'Donoghue, 2006; Hughes & Bartlett, 2002; Bartlett, 2001). Williams *et al.* (2005) investigated the changes to match and ball-in-play time in the Six Nations, Tri-Nations, European Cup and Super Rugby competitions over a five-year period (1999-2003) and found that both time variables increased significantly over the period. It was speculated that the increase in ball-in-play time could have increased the continuity, which may have led to increased player actions. The authors stated that the findings were largely due to the law changes implemented during the period of the research. More recently, Austin *et al.* (2011) analysed the match play demands of professional rugby players competing in Super Rugby matches during the 2008 and 2009 seasons. They found that between the two seasons there had

been an increase in total high-intensity activities completed, sprint frequencies and work-to-rest ratios across all playing positions. In order for teams to remain competitive in Super 14 rugby, the training of teams needs to reflect the current match play demands. Eaves and Hughes (2003) identified the changes that occurred to the time and frequency of activity and ball recycling in international rugby matches. They found that players were performing activities significantly more quickly and more frequently, while total game activity had also increased. Similarly, the frequency of rucks had increased and although the speed of ball recycle had been consistent, the results suggested that the game activity patterns might have shifted towards a faster ruck-dominated game with more phases of play. They stated that the game had become more physically demanding since the introduction of professionalism and that the law changes implemented during the period had made an impact on playing style and strategies used by the different teams. Thus, with the profile of the game changing, the training of players needs to reflect the current demands of the game and take advantage of the law changes and the effects thereof on the physical demands of match play. These changes need to be monitored and implemented in the design of training programmes in order for teams to remain competitive.

It has been well established that the physical demands of the game during competitive match play are changing and that coaches and trainers need to understand the physical demands and adapt their programmes in order to implement more specific training programmes that meet the demands of the modern game (Austin *et al.*, 2011; Duthie *et al.*, 2003; Eaves & Hughes, 2003). Research on physical demands and match profiles needs to be done; however, there is research, although limited, which identifies practical solutions for coaches and trainers to implement research findings in their programme design. Therefore the aim of this study was to compare the 2007 and 2013 seasons of the South African Currie Cup Tournament in order to determine the impact of law changes on time variables.

4.2 Methodology

4.2.1 Sample population

The video recordings of the South African Currie Cup rugby tournament during the 2007 and 2013 rugby seasons were used for the purpose of this study. A total of 70 matches were analysed, 2007 (n= 37) and 2013 (n=33).

4.2.2 Procedure of testing

Video recordings

The video recordings of the Currie Cup matches were supplied by Fika, the official analyst company of the tournament. The recorded matches were analysed using the Dartfish 6.0 TeamPro software package.

Coding

The performance indicators (Table 4.1) were analysed by the coding function of the Dartfish software package. The video files were viewed and coded in the software tagging panel. A tagging panel was created by the researcher, who is a qualified Dartfish tagging and video analyst. The panel allowed a key press to translate into a PI. To provide a detailed analysis, several PIs were entered into the panel.

4.2.3 Performance indicators

In Table 4.1 are the PIs analysed based on the law changes and amendments.

Table 4.1 Performance indicators and definitions of the time interval and contact profile

Performance Indicator	Definitions
Time interval profile	
Total match time	The time taken to complete the match. The time starts when the team starting the match kicks off, to the time the referee ends the match.
Total ball in play	The total time the ball is in play in which teams may compete for the ball, until it leaves the field of play or the referee stops the game
Match stoppage	The time taken from when the ball is deemed out of play (dead) until the game is restarted and the ball becomes available. The match stoppage time starts when the ball has entered the playing field and ends when it is out of the field of play or the referee stops the game.
Kicking stoppage	The time taken for a kicker to attempt a kick at goal. The time starts when the referee signals a kick will be attempted, and stops when the referee signals the ball has successfully gone through the posts or when the ball has gone dead.
Injury stoppage	The time taken for an injured player on the field to be treated by medical staff. The injury stoppage time starts once the referee stops the match time and signals for medical assistance and ends once he starts the match timer.

Television match official (TMO) stoppage	The time taken for the TMO to make a decision. The TMO stoppage time starts once the referee signals the TMO for assistance and ends once the referee blows his whistle to continue play.
Total stoppages	The sum total of all stoppage times (match, injury, TMO, and kicking stoppage times).
Team possession	A continuous possession period for either team. Said possession is ended when it is passed over to the opposition. This does not include ball out of play, therefore the time is determined only on ball-in-play time.
Total phase activity	The sum total of all individual activity times.
Individual phase activity	The time between subsequent breakdowns (rucks). Phase activity starts with the ball being introduced into play either by exiting a scrum, line-out or ruck and ends when a ruck is formed or when the ball is dead.
Contact profile	
Total contact time	The sum total of all contact times (tackle, rucks/mauls, scrum, line-out times).
Tackle time	The total time players are in physical contact with one another. The tackle time starts when an opposing player makes contact with the ball carrier and ends if a ruck/maul is formed or if the opposing player releases the ball carrier.
Rucking/mauling time	The total time players are involved in a ruck and maul. The rucking/mauling time starts as soon as a ruck is formed and ends when the ball leaves the ruck/maul.
Scrum time	The total time players spend in a scrum. The scrum time starts when the ball enters the scrum and ends once the ball has left the scrum.
Line-out time	The total time players spend in a line-out. The line-out time starts when the ball leaves the hooker's hands and ends once the ball has left the jumper's hands either by him throwing it to another player or forming a ruck/maul once he is on the ground.

Work-to-rest ratios

The duration of different time periods and player activities (*ball in play, total phase activity, total contact time*) was used to calculate the work-to-rest ratios during match play. The work-to-rest ratios were determined by comparing the time of the *ball in play*, *total phase activity* and *total contact* (work periods) to the *total stoppage time* (rest time).

Reliability

To ensure acceptable reliability, intra-observational tests were undertaken for all variables with the level of agreement exceeding 95%. For intra-observational procedures, the analyst randomly selected 25% of matches and viewed them under the same conditions.

4.2.4 Statistical analysis

The statistical data processing package (Statsoft Inc., 2011) was used to process the data. Descriptive statistics (means and standard deviations) were reported and a significance level of 5% ($p < 0.05$) was used as guideline for determining significant differences. Mixed-model repeated-measures ANOVA was used to compare halves and years, with halves treated as within subjects fixed factor and year as between subjects fixed factor. The matches analysed (nested in year) were treated as random effect. Spearman correlation coefficient was used to determine the reliability. Intra-rater agreement were interpreted as follows: poor (0.0.20), fair (0.30-0.40), moderate (0.50-0.60), strong (0.70-0.80), and almost perfect (>0.80). Analysis showed that each variable revealed an almost perfect agreement. The work-to-rest ratios were determined by comparing the time of the work periods to the rest time.

4.3 Results

The results will be discussed under the following headings: *time interval profile* and *contact profile*.

Time interval profile

The results for the time interval profile, displayed in Tables 4.2 and 4.5, indicated that the *total match time* increased significantly from 2007 to 2013 (46:34 ± 03:08 vs 47:28 ± 03:42, $p < 0.01$), particularly during the 2nd half of both years ($p = 0.02$, $p < 0.01$). The *total ball-in-play time* showed a significant decrease from 2007 to 2013 (17:21 ± 02:27 vs 16:02 ± 02:22, $p < 0.01$). Despite the decrease the 2nd half of both years remained the longest ($p = 0.04$, $p < 0.01$).

The *total stoppage time* therefore increased significantly from 2007 to 2013 (23:14 ± 03:47 vs 32:05 ± 03:42, $p = 0.01$), with the *match stoppage time* (20:08 ± 02:06 vs 21:44 ± 02:06, $p < 0.01$) and *TMO stoppage time* (01:21 ± 01:16 vs 02:15 ± 02:11, $p < 0.01$) being the main contributors to the increase in *total stoppage time*. Although the *kicking stoppage time* showed

no significant change (p = 0.52), the 2nd half of both years showed a significant decrease (p = 0.02).

The *total phase activity* showed no significant change (p = 0.94), yet the 2nd half duration of both years was the longest (p < 0.01, p < 0.01). However, the *individual phase activity* showed a significant decreased from 2007 to 2013 (00:06 ± 00:01 vs 00:05 ± 00:01, p < 0.01). The work-to-rest ratios, displayed in Tables 4.3 and 4.6, revealed that the *ball-in-play* ratio increased significantly from 2007 to 2013 (1:1.8 vs 1:2.1, p < 0.01). The *total phase activity* also showed a significant increase from 2007 to 2013 (1:3 vs 1:3.5, p = 0.03).

Table 4.2 Time interval profile descriptive statistics for the 2007 and 2013 seasons

Time interval PI	**2007** ***n* = 74**	**2013** ***n* = 66**	**p-value$_1$**	**p-value$_2$**	**r-value**
Total match time	**46:34 ± 03:08**	**47:28 ± 03:42**	**<0.01***	**0.26***	**0.99**
Total ball in play	**17:21 ± 02:27**	**16:02 ± 02:22**	**<0.01***	**0.11**	**0.99**
Total stoppage	**23:14 ± 03:47**	**32:05 ± 03:42**	**<0.01***	**0.91**	**0.99**
Match stoppage	**20:08 ± 02:06**	**21:44 ± 02:06**	**<0.01***	**0.50**	**0.99**
Kicking stoppage	05:52 ± 02:02	06:13 ± 02:09	0.52	0.93	**0.99**
Injury stoppage	03:13 ± 02:07	02:34 ± 02:33	0.23	0.72	**0.99**
TMO stoppage	**01:21 ± 01:16**	**02:15 ± 02:11**	**<0.01***	**0.95**	**0.99**
Team possession	00:16 ± 00:02	00:20 ± 00:04	0.57	0.32	**0.99**
Total phase activity	09:51 ± 01:17	09:46 ± 01:58	0.94	0.74	**0.99**
Individual phase activity	**00:06 ± 00:01**	**00:05 ± 00:01**	**<0.01***	**0.14**	**0.85**

*Note: p-value$_1$: differences between the 2007 and 2013 seasons; p-value$_2$: interaction effect between both halves of the 2007 and 2013 seasons; p-value$_2$: interaction effect between both halves of the 2007 and 2013 seasons; * = statistically significant difference between the 2007 and 2013 seasons; ** = a trend towards statistically significant difference between the 2007 and 2013 seasons; r-value: reliability correlation coefficient.*

Table 4.3 Work-to-rest ratios for the 2007 and 2013 seasons

Work-to-rest ratios	2007 *n* = 74	2013 *n* = 66	p-value$_1$	p-value$_2$
Ball in play	**1:1.8**	**1:2.1**	**<0.01***	0.14
Total phase activity	**1:3**	**1:3.3**	**0.03***	0.75
Total contact	1:3.3	1:3.5	0.29	0.14

*Note: p-value$_1$: differences between the 2007 and 2013 seasons; p-value$_2$: interaction effect between both halves of the 2007 and 2013 seasons; p-value$_2$: interaction effect between both halves of the 2007 and 2013 seasons; * = statistically significant difference between the 2007 and 2013 seasons; ** = a trend towards statistically significant difference between the 2007 and 2013 seasons.*

Contact profile

The contact profile results revealed that the *total contact time* showed no significant change in duration; however, the 2nd half in 2013 showed a significant increase ($p < 0.01$) (Tables 4 and 7). The *tackle time* showed a significant increase from 2007 to 2013 (03:06 ± 01:04 vs 03:30 ± 01:04, $p < 0.01$), particularly in the 2nd half of both years ($p < 0.01$, $p < 0.01$). The *ruck/maul time* decreased significantly from 2007 to 2013 (06:00 ± 01:20 vs 05:00 ± 01:06, $p < 0.01$), yet the 2nd half of both years maintained the longest duration ($p < 0.01$, $p < 0.01$).

The *scrum time* showed a significant decrease from 2007 to 2013 (00:47 ± 00:20 vs 00:39 ± 00:21, $p < 0.01$)**,** while the *line-out time* also significantly decreased (00:50 ± 00:10 vs 00:39 ± 00:14, $p < 0.01$).

Table 4.4 Contact profile descriptive statistics for the 2007 and 2013 seasons

Contact profile PI	2007 *n* = 74	2013 *n* = 66	p-value$_1$	p-value$_2$	r-value
Total contact time	09:23 ± 02:03	10:04 ± 04:50	0.16	0.05**	**0.99**
Tackle time	**03:06 ± 01:04**	**03:30 ± 01:04**	**<0.01***	0.90	**0.99**
Ruck/Maul time	**06:00 ± 01:20**	**05:00 ± 01:06**	**<0.01***	0.14	**0.99**
Scrum time	**00:47 ± 00:20**	**00:39 ± 00:21**	**<0.01***	0.66	**0.99**
Line-out time	**00:50 ± 00:10**	**00:39 ± 00:14**	**<0.01***	0.99	**0.98**

*Note: p-value$_1$: differences between the 2007 and 2013 seasons; p-value$_2$: interaction effect between both halves of the 2007 and 2013 seasons; p-value$_2$: interaction effect between both halves of the 2007 and 2013 seasons; * = statistically significant difference between the 2007 and 2013 seasons; ** = a trend towards statistically significant difference between the 2007 and 2013 seasons; r-value: reliability correlation coefficient.*

Table 4.5 Time interval profile descriptive statistics for the 1st and 2nd halves of matches for the 2007 and 2013 seasons

Time interval PI	2007 1st Half *n* = 37	2007 2nd Half *n* = 37	2013 1st Half *n* = 33	2013 2nd Half *n* = 33	2007 1st & 2nd Half p-value$_1$	2013 1st & 2nd Half p-value$_2$	2007 vs 2013 1st Halves p-value$_3$	2007 vs 2013 2nd Halves p-value$_4$
Total match time	**45:09 ± 02:55**	**47:20 ± 03:36**	**46:25 ± 03:10**	**49:11 ± 03:50**	**0.02***	**<0.01***		**<0.01***
Total ball in play	**16:36 ± 01:84**	**17:26 ± 02:57**	**15:06 ± 02:01**	**16:59 ± 02:40**	**0.04***	**<0.01***	**<0.01***	
Total stoppage	**29:13 ± 03:28**	**29:54 ± 04:06**	**31:19 ± 03:31**	**32:12 ± 04:25**			**<0.01***	**<0.01***
Match stoppage	**19:56 ± 03:01**	**20:59 ± 02:46**	**21:18 ± 02:48**	**22:10 ± 03:03**	**0.05****		**<0.01***	**0.07****
Kicking stoppage	**06:36 ± 02:32**	**05:07 ± 02:04**	**06:20 ± 02:25**	**05:26 ± 01:38**	**0.02***	**0.02***		
Injury stoppage	02:51 ± 01:53	03:35 ± 02:20	02:02 ± 01:57	03:06 ± 02:21				
TMO stoppage	**01:10 ± 01:34**	**01:33 ± 01:34**	**02:20 ± 02:00**	**02:51 ± 02:17**		**0.04***	**<0.01***	**<0.01***
Team possession	00:16 ± 00:02	00:17 ± 00:03	00:19 ± 00:04	00:21 ± 00:05				
Total phase activity	**09:26 ± 01:18**	**10:16 ± 01:09**	**09:10 ± 02:13**	**10:22 ± 01:30**	**<0.01***	**<0.01***		
Individual phase activity	**00:05 ± 00:01**	**00:06 ± 00:01**	**00:06 ± 00:02**	**00:05 ± 00:01**	**<0.01***		**0.03***	**<0.01***

*Note: p-value$_1$: differences between the 2007 and 2013 seasons; p-value$_2$: interaction effect between the halves of the 2007 and 2013 seasons; * = statistically significant difference between the 2007 and 2013 season; ** = a trend towards a statistically significant difference between the 2007 and 2013 seasons.*

Table 4.6 Work-to-rest ratios for the 1st and 2nd halves of matches for the 2007 and 2013 seasons

Work-to-rest ratios	2007		2013		2007	2013	2007 vs 2013	2007 vs 2013
	1st Half	2nd Half	1st Half	2nd Half	1st & 2nd Half	1st & 2nd Half	1st Halves	2nd Halves
	n = 37	*n* = 37	*n* = 33	*n* = 33	p-value$_1$	p-value$_2$	p-value$_3$	p-value$_4$
Ball in play	**1:1.8**	**1:1.8**	**1:2.2**	**1:1.9**			**<0.01***	**0.03***
Total phase activity	1:3.1	1:2.9	1:3.5	1:3.2				
Total contact	**1:3.4**	**1:3.2**	**1:3.7**	**1:3.2**		**<0.01***		

*Note: p-value$_1$: differences between the 2007 and 2013 seasons; p-value$_2$: interaction effect between the halves of the 2007 and 2013 seasons; * = statistically significant difference between the 2007 and 2013 seasons; ** = a trend towards a statistically significant difference between the 2007 and 2013 seasons.*

Table 4.7 Contact profile descriptive statistics for the 1st and 2nd halves of matches for the 2007 and 2013 seasons

Contact profile PI	2007		2013		2007	2013	2007 vs 2013	2007 vs 2013
	1st Half	2nd Half	1st Half	2nd Half	1st & 2nd Half	1st & 2nd Half	1st Halves	2nd Halves
	n = 37	*n* = 37	*n* = 33	*n* = 33	p-value$_1$	p-value$_2$	p-value$_3$	p-value$_4$
Total contact time	**09:18 ± 01:49**	**10:08 ± 02:06**	**09:00 ± 01:59**	**11:48 ± 06:26**		**<0.01***		**0.02***
Tackle time	**02:46 ± 01:04**	**03:26 ± 00:59**	**03:09 ± 00:57**	**03:52 ± 01:05**	**<0.01***	**<0.01***	**<0.01***	**<0.01***
Ruck/Maul time	**05:34 ± 01:07**	**06:26 ± 01:28**	**04:51 ± 01:31**	**05:49 ± 01:39**	**<0.01***	**<0.01***	**<0.01***	
Scrum time	**00:48 ± 00:20**	**00:47 ± 00:19**	**00:41 ± 00:23**	**00:36 ± 00:19**				**0.04***
Line-out time	**00:50 ± 00:11**	**00:49 ± 00:11**	**00:39 ± 00:17**	**00:38 ± 00:11**			**<0.01***	**<0.01***

*Note: p-value$_1$: differences between the 2007 and 2013 seasons; p-value$_2$: interaction effect between the halves of the 2007 and 2013 seasons; * = statistically significant difference between the 2007 and 2013 seasons; ** = a trend towards a statistically significant difference between the 2007 and 2013 seasons.*

4.4 Discussion

The aim of this study was to compare the 2007 and 2013 seasons of the South African Currie Cup tournament in order to determine the impact of law changes on time variables. The study also underlined the importance of analysing rugby matches as two separate halves when comparing time variables. Combining the data of both halves may still identify significant differences, but the differences found may only have been contributed by a change in one half and not the other. Table 4.8 provides a summary of the law changes and the possible effects thereof on the time variables.

Table 4.8 Summary of the law changes and the effect thereof on the game

Law change	Description	Effect
Law 6.A.6: Referee consulting with others	Extension of the jurisdiction of the TMO	Increased the total stoppage time, which in turn increased total match time.
Law 12.1 (f) Outcome of a knock-on or throw forward into touch	Knock-on or throw forward into touch. When the ball goes into touch from a knock-on or throw forward, the non-offending team will be offered the choice of a line-out at the point the ball crossed the touch line, or a scrum at the place of the knock-on or throw forward. The non-offending team may exercise this option by taking a quick throw-in.	Increased match stoppage time.
Law 16.7 (c) : Unsuccessful end to a ruck	When the ball has been clearly won by a team at a ruck and is available to be played the referee will call "use it", after which the ball must be played within five seconds. If the ball is not played within the five seconds the referee will award a scrum and the team not in possession of the ball at the ruck will be awarded the throw-in.	Reduced ruck/maul time, increased tackle time and reduced individual phase activity.
Law 19.2: Quick throw-in	For a quick throw-in, the player may be anywhere outside the field of play between the line of touch and the player's goal line.	Increased match stoppage time and reduced line-out time.

Law 20.1 (g): Forming a scrum	The referee will call "crouch" then "touch". The front rows crouch and, using their outside arm, each prop touches the point of the opposing prop's outside shoulder. The props then withdraw their arms. The referee will then call "set" when the front rows are ready. The front rows may then engage. The "set" call is not a command but an indication that the front rows may come together when ready.	Decrease in scrum time and number of scrum resets
Law 21.4 (c) to (l) Penalty and free-kick options and requirements	Line-out alternative. A team awarded a penalty or a free kick at a line-out may choose a further line-out and will have the throw-in. This is in addition to the scrum option.	Increased match stoppage time.

The results of the time interval profile, displayed in Tables 4.2 and 4.5, demonstrated that the *total match time* increased significantly, with the *total ball-in-play time* decreasing significantly and the *total stoppage time* increasing significantly. It has been established that the *total match time* and *total stoppage time* increased in several tournaments (Six Nations, Tri-Nations, Super Rugby and European Cup) (Williams *et al*., 2005); however, the significant decrease in *ball-in-play time* differs from previous studies (Eaves & Hughes 2003, William *et al*., 2005). Williams *et al*. (2005) investigated the changes in match and ball-in-play time that occurred over a five-year period (1999-2003) and found that both time variables increased significantly over the period. It was stated that the findings were largely due to the law changes implemented during the period. The findings in this study suggest that the law changes, which attempt to improve continuity, have not directly affected the *total ball-in-play time*.

The increase in *total match time* has been due to the significant increase in the *total stoppage time*. The primary reason for the increase in *total stoppage time* has been the introduction of **Law 6.A.6, referees consulting with others**, which has increased the use of the television match official (TMO). The amendment to the law, allowing referees to consult with the TMO, had an effect that led directly to an increase in the *total stoppage* and *total match time*. Similar results were found in the 2013 Rugby Championship and Six Nations Championship, with referees utilising the TMO frequently with referrals and in some situations taking as long as

03min:11sec (IRB, 2013a; IRB, 2013b). The *match stoppage time* has also shown a significant increase. Several law changes may be responsible for this increase: a) **Law 6.A.6, referees may be consulting with assistant referees more frequently as there may be more infringements and/or off-the-ball player actions that referees are not identifying;** b) **Law 12.1 (f), when the ball goes into touch from a knock-on or throw forward, the non-offending team will be offered the choice of a line-out or scrum**. This means that once the ball has gone out of the field of play the referee must first consult teams on their decision of either a line-out or scrum, after which the subsequent set piece must be formed, which takes additional time. The same can be said for **Law 21.4 (c) to (l), in which a team awarded a penalty or a free kick at a line-out may choose a further line-out, in addition to the scrum option**. Referees must consult the team about their decision and take additional time to set up the requested set piece; c) **Law 19.2, quick throw-ins may be anywhere outside the field of play between the line of touch and the player's goal line**. Once the ball has been collected by a player outside the field of play, players may be running forward towards the line of touch in order to gain more ground, which extends the time the ball is outside the field of play. Additionally, teams may be adopting a tactical approach on the field by: a) kicking the ball out of the field of play more frequently for territorial gain or to relieve pressure; b) choosing to not quick-tap the ball but rather kick the ball into touch to set up an attacking line-out in order to create a good foundation from which to attack; c) use replacements/substitutes more regularly, which takes time for players to enter and leave the field of play. It could also be suggested that players may not be accustomed to the new law changes, therefore they repeatedly infringe the laws of the game, which would halt the flow of the match. It should be noted that although there was no significant change in the *kicking stoppage time* over the seasons, there was a significant decrease in time in the 2nd halves. This could be due to the pressure on teams to score in the 2nd half, whereby the kickers take their conversion and/or penalty kicks much more quickly in order for the match to restart sooner. Certain law changes have led to matches taking longer to complete, primarily due to the increased duration of stoppages. The increase in *total stoppage time* and the decrease in total *ball-in-play time* have therefore changed the work-to-rest ratio of the ball-in-play time, as seen in Tables 4.3 and 4.6.

The *total phase activity time* showed no significant change over the two seasons; however, there was a significant decrease in the *individual phase activity*, as seen in Tables 4.2 and 4.5. The reduction in time between subsequent breakdowns could be attributed to the introduction of **Law 16.7 (c), unsuccessful end to a ruck, which indicates that when the ball has been**

clearly won by a team at a ruck and is available to be played the referee will call "use it", after which the ball must be played within five seconds. The addition of the five-second countdown at the rucks may have caused a change in tactics or playing style by both teams. With the teams having a time limit to use the ball once it is available, they may in some situations be requested by the referee to use the ball regardless of whether there are any attacking options available. Hence the attacking team may be forced to play the ball and may be setting up another ruck in order to give the line of attack time to regroup to create an effective attacking option. Additionally, attacking teams may be choosing to adopt a more ruck-dominant pattern of play whereby they would be attacking closer to the advantage line, opting for a more flat line of attack before playing the ball deep or wide. This will possibly utilise the forward players more frequently and create more contact situations while decreasing the average *individual phase activity*. At the same time, defending teams may close down space by making use of a rush defensive approach (Hendricks *et al*., 2013; Eaves *et al*., 2008). Hendricks *et al*. (2013), investigated defensive strategies used in the Super 14 competition and concluded that the defensive speed, speed of the defensive in response to the attacking line, had significantly increased and was a significant predictor of breakdown success as this strategy prevented the attacking teams from advancing towards the gain line.

It has been suggested that the reduction of time between subsequent breakdowns is the result of the increase in open-play intensity (Van Rooyen *et al*., 2010; Eaves *et al*., 2008; Eaves & Hughes, 2003). This is highlighted by the significant decrease in *ruck/maul time*, which suggests that the recycling speed of the ball has increased. Eaves and Hughes (2003) analysed patterns of play of international rugby teams before and after the introduction of professionalism. The authors suggested that the game pattern had changed to a more ruck-dominant pattern of play. The increase in ruck frequency and in recycling ball speed indicated a faster and possibly more expansive game. Similar results were found by Eaves *et al.* (2008) when analysing the impact of law changes on time variables in rugby league. The authors found that mean ruck times decreased significantly with teams attempting to increase recycling ball speed, and that the non-significant change in activity time and increase in ruck speed reflect changes in playing strategies. Van Rooyen *et al*. (2010) found similar results when analysing ruck frequency as a predictor of success in the 2007 Rugby World Cup tournament and suggested that the nature of professional rugby had changed and one should expect to see a faster-paced, ruck-dominated game. Therefore the introduction of the **Law 16.7 (c)** may have changed the pace of the game, creating a faster and more ruck-dominant style of play, which

in turn may have influenced the playing strategies used by different teams. This seems evident, particularly in the 2nd half of the 2013 season, as the increase in *total match time* and *total ball-in-play time* coupled with the increase in *total contact time*, *tackle time* and *ruck/maul time* all showed significant increases in the 2nd half. The change in activity duration, together with the *total stoppage time* increasing, has changed the work-to-rest ratio of the *total phase activity*, as seen in Tables 4.3 and 4.6.

The results of the contact profile, displayed in Tables 4.4 and 4.7, revealed that the *total contact time* showed no significant change; however, all the PIs that form part of the *total contact time* showed a significant change. The *tackle time* significantly increased, while the *ruck/maul time* decreased significantly. This suggests that players may be attempting to dominate the tackle situation rather than commit numbers to the rucks and delay the release of the ball. As previously mentioned, the introduction of **Law 16.7 (c)** may have changed the pace of the game and together with the recycling ball speed increasing (decrease in *ruck/maul time*) could suggest that teams may not have enough time to commit players to the rucks and players scanning the contact situations would rather commit to the defensive lines in order to apply pressure and possibly gain possession. This would mean teams are adopting a more defensive strategy, whereby they sacrifice the possibility of winning turnovers at the breakdown (lowering ruck time) by committing more players to the defensive line, favouring more numbers on defence, creating more frequent tackle situations (Prim *et al.*, 2006; Kraak & Welman, 2014). The increase in *tackle time* could also be contributing to the growth in size, strength and speed of players (Fuller *et al.*, 2013). Players who are stronger and more powerful may be more difficult to tackle, hence once the initial impact is made the tackler may only be slowing down the ball carrier until he can overpower him or wait until supporting players assist to bring the ball carrier to ground. Alternatively, players may be executing more effective tackling techniques whereby, once the contact is made, the tackler is utilising a more powerful leg drive that drives the ball carrier backwards, lengthening the time spent in the tackle (Hendricks & Lambert, 2010).

The *scrum time* and *line-out time* both showed a significant decrease in duration. This decrease in set pieces could be attributed to the following: a) introduction of **Law 20.1 (g), new formation of a scrum**, may have reduced the number of scrum collapses and therefore the total number of scrums; b) introduction of **Law 19.2, increased range of a quick throw-in**, may have reduced the number of line-outs as players are utilising quick throw-ins more regularly to

continue play soon; c) players may be kicking less and making fewer handling errors, which would reduce the number of set pieces. Van den Berg and Malan (2012) found a similar decrease in scrums and line-outs when they determined the effect of the experimental law variations on the Super 14 Rugby tournament. They concluded that the increase in action activities that promote continuity suggests that the experimental law variations were successful in promoting a more continuous game. Therefore the introduction of **Law 20.1 (g)** and **Law 19.2** has been successful in improving the continuity of the game by reducing the number of set pieces.

Practical applications

Based on the effect of the law changes on time variables, displayed in Table 4.8, the next section will recommend practical applications to coaches and trainers to assist with the development of rugby-specific training programmes.

Monitoring of teams and players

Performance profiles for individual players, and possibility opponents, should be developed to help trainers and medical staff understand the physical demands made on the players and the team. Recordings of player actions coupled with GPS data could be used to build and develop these profiles and later be used to identify trends in performance. Research on muscle damage and recovery among rugby players during matches has shown that the degree of muscle damage and neuromuscular fatigue was related to the number of impacts sustained in a match (Garraway *et al.*, 2014; Quarrie *et al.*, 2013; McLellan & Lovell, 2012; Hendricks & Lambert, 2010). Analysts could identify the number of contact situations per player, together with distances covered and speeds achieved (with the use of time-motion analysis), which coaches, trainers and medical staff could use when monitoring player performances. This information will allow for more specific recovery protocols and training loads and activities, tailored to meet each player's needs and demands. Additionally, analysts could record the match performances of each encounter, against every opponent. Physical PI could be used to then determine which opponents are more physical and which prefer a more open running style of play. Analysts could then begin formulating a physical match difficulty index, which could be used to periodise tournaments and possibly predict performances for each team (Robertson & Joyce, 2014).

Skills coaching

Contact sessions should primarily focus on executing effective tackling techniques, by which players enter the contact with a relatively low body position to remain stable, and once contact is made players must drive powerfully with the legs to drive the ball carrier backwards, dominating the contact situation (Wheeler *et al.*, 2013; Worsnop, 2012; Hendricks & Lambert, 2010). Additionally, contact sessions should also look at executing fast and effective means of contesting at breakdown points and improving defence speed (speed of defence in response to the attacking line) (Hendricks *et al.*, 2013). Game-specific drills should also aim to teach players decision-making skills by placing them in situations they must read and determine the best plan of action (Kraak & Welman, 2014).

Conditioning of players and teams

Training programmes should put more emphasis on developing players around various contact situations, more specifically the breakdown situation. This must be of high importance for developing forwards, as they participate in the most contact situations during a match (Quarrie *et al.*, 2013). The use of strongman-based exercises and wrestling exercises should be considered as these develop functional strength that closely matches movements required in tackle situations (Corcoran & Bird, 2009).

It has been well documented that rugby requires short bouts of high intensity (McLellan & Lovell, 2012; Corcoran & Bird, 2009; Duthie *et al.*, 2003) and although matches last 80 minutes or more, the actual activity time during which players are required to perform various activities, remains fairly short. With such high demands made on strength and power adaptations and the incompatibility of endurance training and strength development, engaging in frequent aerobic endurance training would interfere with strength and power development (Jones *et al.*, 2013). A more specific method of training metabolic systems for rugby would be to implement repeated high-intensity exercises or high-intensity interval training (Austin *et al.*, 2011; Laursen & Jenkins; 2002). Additionally, the use of cluster sets in resistance training to develop power offers a specific metabolic and neural adaptation similar to rugby (Hansen *et al.*, 2011). These forms of training match the pattern of play rugby players engage in and with the assistance of the work-to-rest ratios and individual phase activity times, intervals can be tailored to meet the specific activity patterns teams or individuals are put through during match play.

With the various contact times measured, trainers can determine specific durations of muscle tension experienced by players. This can be used to design specific resistance training programmes aimed at overloading and strengthening players for specific contact situations and actions in the game. When formulating sets and repetitions, trainers can calculate the duration/muscle tension time at which players are conducting the set of repetitions, coupled with the work-to-rest rations to determine the rest intervals. Furthermore, trainers can time each movement of an exercise (concentric, isometric, eccentric) and lengthen the time of any particular position to place emphasis on that neuromuscular response. An example of this would be performing a bench press with a rhythm of 1-2-5. With the eccentric movement of an exercise associated with the development of strength gains, trainers could put emphasis on that particular movement extending the time. Additionally, with tackle times increasing and players driving forward once tackles are made, trainers could put emphasis on the isometric holding of an exercise.

4.5 Conclusion

In conclusion, the study firstly revealed that the profile of the game has changed to a more continuous game dynamic, with the time spent at rucks/mauls and between subsequent rucks/mauls decreasing, with fewer set pieces (scrums and line-outs). Secondly, the match duration has increased due to an increase in the total stoppage time, primarily caused by an increased use of the TMO. The results from this study emphasised the importance of further research on match and tournament profiles and identifying specific time variable trends. Future studies should focus on identifying time variables of the under 19 and under 21 Currie Cup tournaments and comparing the differences between the different levels, which could lead to improvements in training regimes and programmes by preparing players for the specific demands of the tournament. Studies should also focus on analysing the changes in the English, European and New Zealand domestic competitions and determining whether there are differences between the nations' domestic competitions.

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CHAPTER FIVE

SUMMARY, CONCLUSIONS, LIMITATIONS AND FUTURE RESEARCH

This chapter is included herewith in accordance with the guidelines of the International Journal of Performance Analysis in Sport (Appendix A).

5.1 Summary

A relatively small amount of published literature exists on the effects of the law changes in rugby union, particularly in a South African context. This thesis sought to provide a detailed analysis, with the use computerised notational analysis, to compare the 2007 and 2013 seasons of the South African Currie Cup tournament in order to determine the effect of the law changes on selected performance indicators. The first objective of this thesis was to compare the 2007 and 2013 seasons of the South African Currie Cup tournament in order to determine the effect of the law changes on the scoring, time interval, general skills and contact profiles. The second objective of this thesis was to compare the 2007 and 2013 seasons of the South African Currie Cup tournament in order to determine the impact of law changes on time variables.

This thesis was presented in four main parts, namely an introduction and problem statement (Chapter One), the theoretical background (Chapter Two) and two research articles (Chapters Three and Four). The article format of the thesis was approved by the Senate of Stellenbosch University and the two research articles were presented in accordance with the guidelines of the specific journals. Chapter One introduced the problem and stated the objectives of this study.

The theoretical background (Chapter Two) focused on performance analysis and how it assists coaches and trainers in training individuals and teams. This chapter highlighted that rugby is a constantly changing sport and that in order to gain the competitive edge over opposing teams coaches need to analyse match play demands to develop effective training programmes. The chapter also highlighted the law changes and/or amendments implemented after the 2007 Rugby World Cup and the limitations of research on law changes.

Chapter Three is in a research article format entitled: *Changes in the match profile of the South African Currie Cup tournament during 2007 and 2013*. The scoring profile revealed that fewer tries were scored ($p = 0.07$), while the number of penalty goals increased significantly ($p < 0.01$). The time interval profile showed that stoppages decreased significantly ($p < 0.01$). The skills profile revealed a significant increase in the number of passes ($p < 0.01$) and a decrease in the number of handling errors, offloads and kicks ($p < 0.01$). The contact profile revealed a significant increase in the number of rucks/mauls and tackles completed ($p < 0.01$) and a decrease in scrums and line-outs ($p < 0.01$). From the results it can be concluded that the profile of the South African game has changed to a more physical and continuous game, with an

increased number of player actions (passing, tackling and rucks/mauls) and a decreased defensive playing style.

Chapter Four is in a research article format entitled: *The effect of the law changes on time variables of the South African Currie Cup tournament during 2007 and 2013*. The time interval profiles revealed that the total match time and total stoppage time increased significantly ($p < 0.01$), while the total ball-in-play time decreased significantly ($p < 0.01$). The individual phase activity also indicated a significant decrease ($p < 0.01$). The contact profile revealed that the total tackle time increased significantly ($p < 0.01$), while the total ruck/maul, scrum and line-out times decreased significantly ($p < 0.01$). From the results it can be concluded that the profile of the South African game has become more continuous, with total time spent at rucks/mauls and between subsequent rucks decreasing.

In summary, the game of rugby in the South African Currie Cup tournament has transformed into a more physical and continuous game, which is ruck dominant. By analysing the match profile, coaches and trainers will be able to adapt their training programmes to meet the specific demands of match play.

5.2 Conclusions

The conclusions drawn from this research study were presented in accordance to the set objectives in Chapter One.

Research Article 1: Compare the 2007 and 2013 seasons of the South African Currie Cup tournament in order to determine the effect of the law changes on the scoring, time interval, general skills and contact profiles.

The study firstly revealed that the profile of the game has changed to a more physical and continuous game, with an increased number of player actions (passing, tackling and rucks/mauls) and a reduced number of stoppages, predominantly in the second half. Secondly, a trend revealed that teams are adopting a more defensive playing style, whereby they sacrifice committing numbers to the breakdowns and rather commit players on defence. This has created a more physically intense match with fewer tries being scored. The introduction of the following laws could be attributed to the possible changes in the match profile: Law 16.7 (c): Unsuccessful end to a ruck, may have increased the number of passes, tackles and rucks, which

in turn would have reduced the number of line breaks and tries scored as the increase in player actions reduced the chance of scoring a try. The increase in the number of player actions may also be the reason why teams may be adopting a more defensive strategy. Law 19.2: Quick throw-in, may have reduced the number of kicks and line-outs as teams may prefer to kick only when put under pressure as limited ground may be gained by kicking. Law 20.1 (g): Forming a scrum, may have reduced the number of stoppages as the number of scrum resets has decreased.

Based on the effect of the law changes, the following is practical information to take into consideration when designing and implementing training programmes. The norm for technical staff is to analyse and record match data as a whole match, but in order to be more specific one could break the match down into two separate halves, as some significant information may be lost when adding the two halves together. For example, one half's PIs may be significantly higher than the other half. Profiles for tournaments and opponents should be developed to help understand what players go through physically and help understand and interpret tactical strength and weaknesses. Analysts could identify the number of contact situations each player is involved in, which coaches, trainers and medical staff could use when monitoring players, implementing recovery strategies and planning training loads. Skill-oriented sessions, kicking in particular, should be a priority in training schedules and should focus on developing players' technical mastery of the skill, as well as developing it in pressure situations. When looking at speed and agility or interval training, training programmes should put emphasis on developing players around the various contact situations in the game and not only the running-based demands. Training sessions that target specific energy systems should not only focus on repeated running movements (accelerating, decelerating) but also include falling down and getting back up, as these movements follow tackles and rucks/mauls. Multi-direction movements should be included in speed training sessions and warm-up plans, as these movements are prominent when players are forming defensive patterns. Backward running and side shuffling, when players are placing themselves on defence, followed by forward movements, stepping forward or jogging should also be included.

Research Article 2: Compare the 2007 and 2013 seasons of the South African Currie Cup tournament in order to determine the impact of law changes on time variables.

The study firstly revealed that the profile of the game has changed to a more continuous game dynamic, with the time spent at rucks/mauls and between subsequent rucks/mauls decreasing, with fewer set pieces (scrums and line-outs). Secondly, the match duration has increased due to an increase in the total stoppage time, primarily caused by an increased use of the TMO. The introduction of the following laws could have contributed to the changes in the match profile: Law 6.A.6: Referee consulting with others, may have increased the total stoppage time, which in turn increased the total match time as referees may be consulting with assistant referees and using the TMO regularly. Law 12.1 (f) Outcome of a knock-on or throw forward into touch, and Law 21.4 (c) to (l) Penalty and free-kick options and requirements, may have increased the match stoppage as referees have to consult with teams on the option of a set piece after the ball is dead. Law 16.7 (c): Unsuccessful end to a ruck, may have reduced the ruck/maul time, increased the tackle time and reduced the individual phase activity. As the ball recycling time has increased, players may be dominating the tackle situation rather than competing for the ball at the breakdowns, thereby increasing the tackle time. Law 19.2: Quick throw-in, may be increasing the match stoppage time as once the ball is collected by a player outside the field of play, players may be running forward towards the line of touch in order to gain more ground, which extends the time the ball is outside the field of play. Law 20.1 (g): Forming a scrum, may have reduced the scrum time and the number of scrum resets as the scrums are collapsing less.

Based on the effect of the law changes, the following is practical information to take into consideration when designing and implementing training programmes. Performance profiles for individual players, and possibility opponents, should be developed to help trainers and medical staff understand the physical demands made on the players and the team. Recordings of player actions coupled with GPS data could be used to build and develop these profiles and later be used to identify trends in performance. Analysts could identify the number of contact situations per player, together with distances covered and speeds achieved, which coaches, trainers and medical staff could use when monitoring player performances. This information will allow for more specific recovery protocols and training loads and activities, tailored to meet each player's needs and demands. Additionally, analysts could record the match performances of each encounter, against every opponent. Physical PIs could be used to then determine which opponents are more physical and which prefer a more open running style of

play. Analysts could then begin formulating a physical match difficulty index. Contact sessions should primarily focus on executing effective tackling techniques. Additionally, contact sessions should also look at executing fast and effective means of contesting at breakdown points and improving defence speed. Training programmes should put more emphasis on developing players around various contact situations, more specifically the breakdown situation. The use of strongman-based exercises and wrestling exercises should be considered as these exercises develop functional strength that closely matches movements required in tackle situations. With the various contact times measured, trainers can determine specific durations of muscle tension players are experiencing. This can be used to design specific resistance training programmes that are aimed at overloading and strengthening players for specific contact situations and actions in the game.

5.3 Limitations

Certain limitations regarding this study can be indicated:

- Firstly, this study identified the profile of the South African Currie Cup tournament. The findings may therefore not reflect the profile of other domestic or international tournaments. It would thus be ideal to analyse other domestic and international tournaments and investigate their profiles as they would provide a better understanding of domestic rugby in several countries, in both the northern and southern hemispheres.
- Secondly, this study analysed only the 2007 and 2013 seasons. There may have been format changes to the tournament that could have affected the profile of the game. It would therefore be ideal to analyse each season of the tournament to identify the changes that could be occurring.
- Lastly, this study investigated only the profile of the senior level of the Currie Cup tournament. The findings may not reflect the under 19 or under 21 Currie Cup tournaments. It would therefore be ideal to investigate each level of the tournament to determine the possible differences in the profiles.

5.4 Future research

The results from this study emphasised the importance of further research on match and tournament profiles and identifying specific time variable trends. Future studies should focus on identifying the profile of the under 19 and under 21 Currie Cup tournaments and comparing the differences between the different levels, which could lead to improvements in training regimes and programmes by preparing players for the specific demands of the tournament. Studies should also focus on analysing the changes in the English, European and New Zealand domestic competitions and determining whether there are differences between the nations' domestic competitions.

APPENDIX A: INTERNATIONAL JOURNAL OF PERFORMANCE ANALYSIS IN SPORT

Instructions for Authors: International Journal of Performance Analysis in Sport

1. Scope

The International Journal of Performance Analysis in Sport is published on behalf of the Centre for Performance Analysis, Cardiff School of Sport at Cardiff Metropolitan University and in association with the International Society of Performance Analysis in Sport. The emphasis is on the analysis of actual performance in sport and exercise. Studies using observational methods, biomechanical analysis, self-report emanating from actual sports performance, qualitative observation and measurements such as heart rate response during actual sports performance are all within the scope of the journal. Laboratory studies of key techniques within sports are also of interest where such techniques are clearly important and cannot be analysed in detail during actual competition. Such techniques include tennis serves and golf swings. There may be other contributions that do not analyse sports performance at all that are within the scope of the journal. For example, interview studies or meta analyses may lead to theoretical contributions explaining the nature of sports performance, tactics used and factors influencing performance. Review articles relevant to sports performance are also welcome. Other topics covered include technologies such as design of analysis systems, sports equipment, research into training, and modelling and predicting performance. Contributors wishing to clarify whether papers they are writing are within the scope of the journal are welcome to contact the general editor.

2. Submission

Authors must submit an original article in electronic form, (preferably by e-mail) in Microsoft Word, to the General Editor (podonoghue@cardiffmet.ac.uk). Papers submitted to the Journal will be refereed blind by acknowledged experts in the subject. Occasionally, where papers are submitted in highly specialist areas outside the expertise of the Editorial Board members, the General Editor may ask authors to provide contact details for potential reviewers who are experts in the area. The General Editor has the final decision on publication. No word limits are specified for papers, but discursive treatments of the subject matter are discouraged. The Journal does not normally publish letters to the editor.

3. Originality

All material submitted for publication in the journal must be accompanied by a statement by the lead author, with the authority of all of the authors, that: the material submitted is original and unpublished, and is not under consideration for publication elsewhere and that the material will not be submitted for publication elsewhere while it is under consideration by the journal.

4. Format

Papers consist of a title page, blind title page and the main text of the paper. Figures and tables should be included in the text rather than following the text. Typical sections of the text are Introduction, Methods, Results, Discussion, Conclusions, any acknowledgements, References and author correspondence details. However, it is acceptable to have a conclusions paragraph at the end of the discussion. Further variation is possible for review articles or where papers report on a series of studies which are best reported in a study by study order.

Page Layout

Pages must be A4 using margins of 3cm at the top, bottom, left and right. Portrait orientation is used except where landscaped orientation clearly assists the presentation of tables and / or figures. Paragraph text should be single spaced.

Title Page

The title page should contain the title (Times Roman, size 18, bold), author names using first names, other initials and surnames and affiliations of authors, the abstract and key words. All text other than the abstract should use Times Roman size 12 font. The abstract should be bold and in italics not exceeding 200 words. It should be inserted in the article after the authors' affiliations and indented by 1 cm at the left and right. The abstract should not contain figures or tables.

Blind Title Page

This should include all of the information on the title page except the author names and affiliations. Where acknowledgements or information in the methods about ethical clearance may compromise the blind reviewing process, the General Editor will temporarily remove this information while the paper is being reviewed.

Headings

Headings and subheadings should all be in Times Roman font, bold and size 12. Headings should be numbered 1., 2., 3., etc with any subheadings being 1.1., 1.2., for example.

Tables

Tables should normally only include horizontal lines to mark the top and bottom and separate column headings from the main body of tables. Tables must be created in word to facilitate any necessary editing by the journal. There are occasions, where correlation tables, for example, require vertical lines and this is acceptable. Table captions should appear above the table.

Figures

Illustrations, photographs, screen dumps, charts, plates and any other artwork should be included in the electronic submission. Authors must have permission to use any photographs within the paper and copyrighted material from published sources must not be included as Figures in the paper. Figure headings should be placed below figures.

Symbols, units and abbreviations

Symbols, units and abbreviations in papers must conform to the Système International d'Unités (SI Units). Authors are advised to consult the National Physical Laboratory publication (R.J. Bell (ed.), 1993, SI: The International System of Units. London: HMSO). For all abbreviations other than units, write the word or words to be abbreviated in full on the first mention followed by the abbreviation in parentheses. If at all possible, group these definitions together near the beginning of the article. As indicated earlier, avoid use of nonstandard abbreviations, especially fabricated ones, within the text; words are much easier to read and follow than abbreviations.

References

References in the text are cited as follows: Smith (1985) ... or (Brown and Green, 1996) ... or, if there are more than two authors, as Jones *et al*. (1993) ... or (Jones *et al*., 1993). Citations of different publications by the same author(s) in the same year are differentiated as Green (1993a) ... (Brown *et al*., 1995b); the a, b, c, etc. , are

normally in order of citation in the text. Multiple citations are listed in ascending chronological order. Multiple publications by the same authors are treated in lists: Smith (1991, 1995), Brown and Green (1992, 1993), Jones *et al*. (1993, 1996a,b); or (Smith, 1991, 1995; Brown and Green, 1992, 1993; Jones *et al*., 1993, 1996a,b). A list of all cited references should be collected at the end of the paper in alphabetical order by, in the first instant, the first author's surname. Where the name of the first author appears more than once, the order is determined by: first, the number of co-authors (zero, one, or more than one); secondly, for one co-author, the first co-author's surname then the year; for two or more co-authors, year then order as dictated by the use of 1990a,b,c (for example) in the citations. The following is an example of how references would be ordered in the reference list: Brown (1980), Brown (1990), Brown and Jones (1977), Brown and Smith (1973), Brown and Smith (1975), Brown *et al*. (1990a), Brown *et al*. (1990b), Brown *et al*. (1990c). Note that the last three examples would all have been cited as Brown et al. in the text, with the a, b and c relating to the order of citation. The names and initials of all authors should be given in the list of references. The style should follow the examples below:

Journal Papers

Newton, P.K. and Keller, J.B. (2005), The probability of winning at tennis, Theory and Data,**Studies in Applied Mathematics**, 114, 214-269.

Books

Ashe, A. (1981), **Arthur Ashe's Tennis Clinic**. London: Heinemann.

Chapters of Edited Books (including conference proceedings published as books)

Hughes, M. and Clarke, S. (1995), Surface effect on elite tennis strategy. In Reilly, T., Hughes, M. and Lees, A. (Eds.) **Science and Racket Sports** (pp. 272-277). London: E & FN Spon.

Conference abstracts published in journals

O'Donoghue, P.G. (2003), The effect of scoreline on elite tennis strategy: a cluster analysis. **Journal of Sports Sciences**, 21, 284-285.

5. Proofs

Once accepted papers have been edited, the PDF versions will be sent to the authors for final checking and final editing.

6. Copyright

Submission of a paper to the International Journal of Performance Analysis in Sport is taken to imply that it represents original, unpublished research and that authors agree that the International Journal of Performance Analysis will have copyright to the material.

APPENDIX B: INTERNATIONAL JOURNAL OF SPORT SCIENCE AND COACHING

Instructions for Authors: International Journal of Sport Science and Coaching

Submission of papers

Manuscripts should be submitted to the relevant editor. Acceptance for publication is subject to the manuscript being an unpublished work. Submission of a manuscript is taken to imply that it is not being considered for publication elsewhere. Submission and acceptance of a paper implies the transfer of copyright to Multi-Science.

Language editing

Your chances of your work being accepted for publication are greatly increased if the work is written in clear and correct English. If you feel your work would benefit from professional language editing, before you submit the manuscript, we recommend you contact www.stallardediting.com

Manuscript preparation

The manuscript must be written in English and should not, normally, exceed 6,000 words. It is essential that all submissions should include two elements: a Word document, or LaTex files; and a PDF.

The metric system is to be used throughout and if it is necessary to quote other units then these should be added in parentheses. The use of unnecessarily complicated notation and formulae should be avoided and the material should be presented in the simplest possible manner.

The manuscript is expected to be written in correct and easily readable English. An author who is not proficient in English is advised to seek help in editing the manuscript before typing. Both English and American spellings are acceptable, but each paper is expected to follow one style consistently.

Running order

Title: in concise form, with wording helping automatic searches, but no superfluous words.

Authors' names: first name in full, other initial(s), family name in full.

Authors' affiliations: postal addresses, e-mail addresses.

Abstract: of less than 150 words written as a 'free standing' paragraph and containing key objectives and conclusions.

1. INTRODUCTION

2. SECTIONS: CAPITALISED HEADINGS; lower case sub heads

X. CONCLUSION

References

Illustrations

The original and one copy of each illustration must be provided. Line drawings must be in a form suitable for direct photographic reproduction. Hand-written lettering is not acceptable. The illustrations should preferably require the same degree of reduction. Please check a copy of the journal to ensure the lettering is large enough to be legible after reduction of the illustration to fit the page or column width. Each illustration must be clearly numbered with the title of the paper written on the reverse side. Captions for illustrations should be typed in numerical order and placed at the end of the manuscript.

It may be possible to reproduce electronic illustration files produced within a programmes such as Excel. If possible please use standard typefaces within the illustration (for example: Arial, Helvetica, Times, etc.).

Photographs

Good quality, clearly reproducible, photographs are encouraged. Electronic files, such as TIFF, JPEG and BMP, are accepted, but please ensure the resolution is equal or above 300 dpi at the required size of reproduction.

Equations

Equations should be numbered sequentially in brackets (..) to the right margin. Within the text, an equation is referred to as 'eqn (..)', or equations as 'eqns (.. - ..)'.

References

References to published work should be numbered sequentially in the order of citation and a reference list in numerical order should be given at the end of the paper.

For an article in a journal, the entry in the reference list must contain the following details:

Name(s) and initial(s) of the author(s), title of article, title of journal (underlined), year of publication, volume number (followed by the issue number in parentheses, if known), initial and final page numbers of the article.

The entry in the reference list for a book must contain the following details:

Name(s) and initial(s) of the author(s), title of book (underlined), edition (unless first edition), publisher, place of publication, year of publication, initial and final page numbers of the part referred to, if applicable.

In the case of an edited book or conference proceedings, the name(s) and initial(s) of the editor(s) should be followed by the abbreviation ed(s). The entry in the reference list for an article in an edited book or conference proceedings must contain the following details:

Name(s) and initial(s) of the author(s), title of article, in: name(s) and initial(s) of the editor(s) followed by the abbreviation ed(s), title of book or proceedings (underlined), publisher, place of publication, year of publication, initial and final page numbers of the article.

The entry in the reference list for a thesis must contain the following details:

Name and initial(s) of the author, title of thesis (underlined), degree awarded, university, year of award, initial and final page numbers of the part referred to, if applicable.

examples:

1. Bourgund, U. and Lawo, M., Optimal Tower Design for a Wind Power System, International Journal of Space Structures, 1985, 1(3), 161-167.

2. Livesley, R.K., Matrix Methods of Structural Analysis, 2nd edn., Pergamon Press, Oxford, 1975.

3. Davies, R.M., ed., Space Structures: Proceedings of the First International Conference on Space Structures, Blackwell Scientific Publications, Oxford, 1967.

4. Mollaert, M., De Wilde, W. and Van Damme, F., Modular Design of Tension Structures, in: Heki, K., ed., Shells, Membranes and Space Frames (vol. 2): Proceedings of the IASS Symposium on Membrane Structures and Space Frames, Elsevier Science Publishers, Amsterdam, 1986, 133-140.

5. Sanchez-Alvarez, J.S., Formex Formulation of Structural Configurations, PhD Thesis, University of Surrey, 1980.

The underlined parts in the reference list will appear in italics in the journal.

Superscript numerals may be used for citation of references in the text. In addition, one may use the abbreviation Ref(s) followed by the reference number(s). Thus one may write: '... Smith[4] and Huxley[5,6,7] have shown that the behaviour is highly nonlinear. Ref. 5 provides a comprehensive list of references relating to the subject and the latest ideas in the field are covered in Refs. 4 and 7 ...' Numbers in square brackets are allowed to be used instead of superscript numerals. Thus one may write: '... Smith [4] and Huxley [5,6,7] have shown that ...'