INCIDENTS AND SANCTIONING OF ILLEGAL AND DANGEROUS RUCK CLEANOUTS DURING THE 2015 TO 2019 UNDER 18 CRAVEN WEEK RUGBY TOURNAMENT

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SUMMARY

Rugby union is one of the most popular team sports worldwide, but because of its physical nature it has a very high injury risk. The high injury risk is a concern for rugby stakeholders, coaches, referees, players and parents. The increased frequency of exposure to rucks and associated injury risk raises serious concerns regarding player safety. Research on ruck cleanouts are limited, with no research performed on ruck cleanouts at elite school level. To date the current study was the first to investigate legal and illegal (both not dangerous and dangerous) ruck cleanouts in order assess player and referee behaviour at elite school level. This thesis followed an article format where two articles were compiled. Article one's aim was to investigate player behaviour by looking at the incident rates for legal and illegal ruck cleanouts, whereas article two aimed to investigate the sanctioning and non-sanctioning rates of illegal ruck cleanouts.

Research article one investigated a total of 35 545 cleanouts of which 91.8 % were legal and 8.16% were illegal. Of the illegal cleanouts 7.5% were regarded not dangerous and 0.6% were dangerous. The majority of illegal not dangerous ruck cleanouts were "*not supporting own body weight*" (f=2 498; 93%; p=0.01), and illegal dangerous were the "*neck roll*" (f=147; 100.0%; p=0.02). The attacking team (f=147; 64.0%, p=0.02) was responsible for more illegal ruck cleanouts when compared to the defending team (f=352; 3.6%). The importance plot of the Classification and Regression Tree Model indicated that the cleaner techniques (1.0) and year (0.3) were the best predictors to classify the ruck cleanout outcomes. When analysing ruck cleanout techniques executed by the attacking and defending teams, the attacking team's "*clearing and protecting*" techniques were significant (p=0.04) for illegal ruck cleanouts both dangerous and not dangerous when compare to other cleanout techniques. When investigating the defending team, the "*jackal*" executed significant ($p \leq 0.0$) more legal cleanouts when compared to the other defending ruck cleanout activities. A big concern highlighted by the current study was that player behaviour worsened during the 2018 and 2019 rugby seasons because of an increase in illegal not dangerous ruck cleanouts from 7 to 21% was found. Player behaviour needs to be addressed, emphasised and improved through correct and effective technique drills during training. The risk of injury during the ruck can be reduced through the implementation of safe and effective techniques by coaches during training. Majority of the sanctioned and not sanctioned ruck cleanouts all took place in Zone B and Channel 3 on the field.

Research article two investigated the sanctioning rate by on-field referees and revealed that 5.0% (f=139) of all illegal (not dangerous and dangerous) ruck cleanouts were sanctioned compared to 95.0% (f=2 765) that were not sanctioned. This study revealed a significant increase (p=0.03) from 2015 to 2016 and a significant decrease (p=0.02) from 2016 to 2017 for sanctioned illegal ruck cleanouts. This is compared to a significant decrease (p=0.03) from 2016 to 2017 and a significant increase (p=0.04) from 2017 to 2018 in illegal not sanctioned ruck cleanouts. The attacking teams made more infringements but were sanctioned less than the defending team. The attacking teams were responsible for 2 362 illegal cleanouts where 1.0% (f=314) were sanctioned and 80.0% (f=2 323) were not sanctioned compared to the defending team that made 314 illegal cleanouts where 3.0% (f=89) were sanctioned and 8.0% (f=225) were not sanctioned by the on-field referee. When investigating player activity at ruck cleanouts, "*clearing and protecting*" was sanctioned significantly (p=0.04) more compared to other attacking techniques and the same was evident for non-sanctioning (p=0.03). With defending player activity, the "*jackal*" was significantly sanctioned (p=0.03) and not sanctioned (p=0.04) compared to other defending activities. The illegal cleanout technique most used was "*not supporting own bodyweight*" for the illegal not dangerous cleanouts, where 96.7% (2 416 out of 2 513) were not sanctioned and 3.3% (82 out of 2 513) were sanctioned. This is compared to the illegal dangerous technique, "*neck roll*", where 95.2% (140 out of 147) were not sanctioned and 4.8% (7 out of 147) were sanctioned by on-field referees. On-field referees need to be stricter and abide by the Laws of The Game in order to prevent dangerous and foul play.

The results found in this study can be used to guide further research around this topic, injury prevention programmes, technique training by focusing on the techniques that cause the majority of illegal not dangerous and illegal dangerous cleanouts, improve referee decision making, modify laws around the ruck cleanout and help players and referees improve their behaviour on the field. Players need to abide by the laws of the game and referees need to be stricter with the enforcement of the laws because this will make the game safer for all involved and lead to an improvement in player behaviour, and therefore, result in a decrease injury risk.

OPSOMMING

Rugby unie is een van die mees populêre spansporte wêreldwyd, maar as gevolg van die fisieke aard van die spel het dit ’n baie hoë beseringsrisiko. Hierdie hoë beseringsrisiko wek rede to kommer vir rugby deelhebbers, afrigters, skeidsregters, spelers en ouers. Die toenemende blootstelling aan losskrums en die daarmee gepaardgaande beseringsrisiko hou groot kommer in vir die veiligheid van spelers. Oor die algemeen is navorsing oor die skoonmaak van losskrums beperk, met geen navorsing wat op elite skoolvlak gedoen is. Tot op datum was die huidige studie die eerste navorsing wat die wettige en onwettige (beide nie gevaarlik en gevaarlik) skoonmaak van die losskrum ondersoek het in ’n poging om speler en skeidsregter gedrag op elite skoolvlak te bepaal. Die tesis, wat in artikel formaat saamgestel is, bevat twee artikels. Die doel van artikel een was om speler gedrag te ondersoek deur te fokus op frekwensie voorvalle vir die wettige en onwettige skoonmaak van losskrums, terwyl artikel twee die bekragtiging en nie-bekragtiging frekwensie voorvalle van die onwettige skoonmaak van losskrums ondersoek het.

Navorsingartikel een het die skoonmaak van 35 545 losskrums ondersoek, waarvan 91.8 % wettig en 8.2% onwettig was. 7.5% van die onwettige skoonmaak prosesse was beskou as nie gevaarlik en 0.64% was gevaarlik. Die oorgrote meerderheid van die onwettige nie gevaarlike skoonmaak prosesse by losskrums was “*ondersteun nie eie liggaamsgewig*” (f=2 498; 93%; p=0.01) en onwettig gevaarlik was die “*nek rol*” (f=147; 100%; p=0.02). Die aanvallende span (f=147; 64%; p=0.02) was verantwoordelik vir meer onwettige losskrum skoonmaak prosesse in vergelyking met die verdedigende span (f=352; 3.6%). Die “Classification and Regression Tree Model” het aangedui dat die skoonmaak tegniek (1.0) en jaar (0.3) was die beste voorspellers om die losskrum skoonmaak uitkomste te bepaal. ’n Analise van die losskrum skoonmaak tegnieke van die aanvallende en verdedigende spanne het getoon dat die aanvallende span se “*skoonmaak en beskerm*” tegnieke tydens die spel betekenisvol was (p=0.04) vir onwettige losskrum skoonmaak aktiwiteite, beide gevaarlik en nie gevaarlik, in vergelyking met ander skoonmaak tegnieke. Met die ondersoek gerig op die verdedigende span, het die “*jackal*” betekenisvol meer (p≤0.00) wettige skoonmaak prosesse uitgevoer in vergelyking met die ander verdedigende losskrum skoonmaak aktiwiteite. Wat groot kommer wek is dat die studie bevind het dat speler gedrag tydens die 2018 en 2019 rugby seisoene versleg het in die sin dat daar ’n toename van 7 to 21% in onwettige nie gevaarlike skoonmaak aktiwiteite was. Die gedrag van spelers moet deur korrekte en effektiewe

tegnieke gedurende inoefeningsessies aangespreek en beklemtoon word en besluitneming moet verbeter word. Die risiko van beserings tydens die losskrum kan verminder word deur die implementering van veilige en effektiewe tegnieke deur afrigters tydens inoefening. Die meeste gesanksioneerde en nie gesanksioneerde losskrum skoonmaak aktiwiteite het almal in Sone B and Kanaal 3 op die veld plaasgevind.

Navorsingartikel twee het die sanksioneringstempo van op-die-veld skeidsregters ondersoek en gevind dat 5.0% (f=139) van alle onwettige (nie gevaarlik en gevaarlik) losskrum skoonmaak aktiwiteite gesanksioneer was in vergelyking met 95.0% (f=2 765) wat nie gesanksioneer was nie. Die huidige studie het ’n betekenisvolle toename (p=0.03) from 2015 tot 2016 gevind en ’n betekenisvolle afname (p=0.02) vanaf 2016 tot 2017 vir gesanksioneerde onwettige losskrum skoonmaak aktiwiteite. Dit is in vergelyking met ’n betekenisvolle afname (p=0.03) van 2016 tot 2017 en ’n betekenisvolle toename (p=0.04) vanaf 2017 tot 2018 in onwettige nie gesanksioneerde losskrum skoonmaak aktiwiteite. Die aanvallende spanne het meer oortredings begaan, maar is minder gestraf as die verdedigende span. Die aanvallende span was verantwoordelik vir 2 362 onwettige skoonmaak aktiwiteite waarvan 1.0% (f=314) gesanksioneer was en 80.0% (f=2 323) nie gesanksioneer was in vergelyking met die verdedigende span wat 314 onwettige skoonmaak aktiwiteite uitgevoer het waarvan 3.0% (f=89) gesanksioneer was en 8.0% (f=225) nie deur deur die op-die-veld skeidsregter gesanksioneer was nie. Met die ondersoek van speler tegnieke by losskrums, “*clearing and protecting*” was betekenisvol meer gesanksioneer (p=0.04) in vergelyking met ander aanvallende aktiwiteite en dieselfde neiging was meer vergelykbaar aan ander aanvallende tegnieke en dieselfde was voor-die- handliggend vir nie gesanksioneerde aktiwiteite (p=0.03). Met verdedigende speler aktiwiteite was die “*jackal*” betekenisvol gesanksioneer (p=0.03) en nie gesanksioneer (p=0.04) in vergelyking met ander verdedigende aktiwiteite. Die onwettige skoonmaak tegniek wat die meeste gebruik is, was “*not supporting own bodyweight*” vir die onwettige nie gevaarlike skoonmaak tegnieke waartydens 96.7% (2 416 uit of 2 513) nie gesanksioneer was nie. Dit is in vergelyking met die onwettige gevaarlike tegnieke, “*neck roll*”, waar 95.2% (140 uit 147) nie gesanksioneer was nie en 4.8% (7 uit 147) deur op-die-veld skeidsregters gesanksioneer was. Op-die-veld skeidsregters moet strenger wees met die toepassing van die Reëls van die Spel om sodoende gevaarlike en ongewensde spel te voorkom.

Die resultate wat deur die studie voortgebring is kan gebruik word om om toekomstige navorsing aangaande die resulate van die huidige onderwerp te stimuleer soos byvoorbeeld, besering voorkomende programme, tegniek inoefening met die fokus op tegnieke wat die meeste onwettige nie gevaarlike en wettig gevaarlike skoonmaak tegnieke insluit, fokus op die tegnieke wat die meeste van die onwettige nie gevaarlike en onwettige gevaarlike losskrum skoonmaak aktiwiteite, verbeter skeidsregter besluitneming, pas reëls aan rondom die losskrum skoonmaak aan en help spelers en skeidsregters om hulle gedrag op die veld te verbeter. Spelers moet die reëls van die spel gehoorsaam en skeidsregter moet strenger wees met die toepassing van die reëls aangesien dit die spel veiliger sal maak vir almal betrokke en aanleiding sal gee tot ‘n verbetering in speler gedrag en daarom sal lei tot ’n afname in die risiko van beserings.

TABLE OF CONTENTS

LIST OF TABLES

Chapter Two

Chapter Three

Chapter Four

Chapter Five

LIST OF FIGURES

Chapter Two

Chapter Four

LIST OF ABBREVIATIONS

CART: Classification and Regression Tree

IRB: International Rugby Board

OSICS: The Orchards Sports Injury Classification

PA: Performance analysis

PI's: Performance Indicators

RFU: Rugby Football Union

SARU: South African Rugby Union

WR: World Rugby

APPENDICES

CHAPTER ONE
INTRODUCTION

Chapter one is included herewith in accordance with the referencing guidelines of the Department of Sport Science, Stellenbosch University.

BACKGROUND

Rugby union (hereafter referred to as rugby) is a contact sport that includes bouts of physical collision interspersed with intermittent high intensity running (Roberts *et al*., 2008; Roberts *et al*., 2013), and has the highest injury incidences. In senior professional male rugby, according to Williams *et al*. (2013) injuries occur at a rate of 81.0 injuries per 1 000 player exposure hours and 46.8 per 1000 player exposure hours in senior amateur rugby (Yeomans *et al*., 2018). In elite English schoolboy rugby competitions Palmer-Green *et al*. (2013) found an injury incidence rate of 35 injuries per 1 000 player exposure hours, while McFie *et al*. (2016) found an injury incidence rate of 22 injuries per 1 000 player exposure hours in South African youth tournaments. Compared to other sports, such as soccer (28 injuries per 1 000 hours exposure), cricket (2 injuries per 1 000

hours exposure) and ice hockey (53 injuries per 1 000 hours exposure) (Fuller & Drawer, 2004), rugby has the highest injury incidences. This is because of its contact nature, where players physically contest for possession of the ball, which results in frequent collisions (Fuller *et al*., 2010; Hendricks & Lambert, 2010; McIntosh *et al*., 2010).

The main causes of injury in rugby are tackles (24 to 58%), rucks (6 to 17%), mauls (12 to 16%), collisions (8 to 9%) and scrums (2 to 8%) (Fuller *et al*., 2007; Posthumus & Viljoen, 2008; Hendricks & Lambert, 2010; Roberts *et al*., 2015). Tackles were the most frequently occurring event that caused the most injuries and days lost through injury. The main causes of injury in schoolboy rugby are tackles in which the ball carrier had the highest injury incidence of 11.3 injuries per 1 000 player exposure hours compared to the tackler (7 injuries per 1 000 player exposure hours), rucks caused 4.4 injuries per player exposure hours (Sewry *et al*., 2019). The common occurrences and high risks for injury during rugby, especially catastrophic injuries like concussion, head/neck, and spinal-cord injuries (Gianotti *et al*., 2009; Viljoen & Patricios, 2012), has led to numerous injury prevention programmes being developed. The six main programmes that were developed are: (1) RugbySmart; (2) Smart Rugby; (3) Rugby Safe; (4) BokSmart; (5) Rugby Ready; and (6) Rugby Seguro. The main aim of these programmes are to reduce the number of catastrophic injuries by educating players, coaches and referees to make the game as safe as possible (Viljoen & Patricios, 2012).

Rugby players attitudes and behaviours towards the safety of the game have been identified as a risk factor for injury (Osberg & Stiles, 2000; Finch *et al*., 2001; Finch *et al*., 2002; Petterson, 2002; Emery *et al*., 2009; Gianotti *et al*., 2009). Player's attitudes and behaviours are included within intrinsic and extrinsic risk factors. Intrinsic risk factors include: body composition; age; attitude; genetics; knowledge and implementation of technique; previous injuries; and physical and mental capacities (Van Mechelen *et al*., 1992; Meeuwisse, 1994; Gissane *et al*., 2001; Bahr & Krosshaug, 2005; McIntosh, 2005). Extrinsic risk factors include: training; behaviour; coaching; environment; and equipment (Van Mechelen *et al*., 1992; Meeuwisse, 1994; Gissane *et al*., 2001; Bahr & Krosshaug, 2005; McIntosh, 2005). All of the above-mentioned risk factors play a role in player injury, and therefore, understanding the attitudes and behaviours of players towards safety will be beneficial in designing and implementing injury prevention programmes (Finch, 2006; Donaldson & Finch, 2012; Hendricks *et al*., 2012; Verhagen *et al*., 2014). Despite this, to date, limited

research was conducted on player behaviours and attitudes in rugby, especially in relation to contact events, which is where the majority of injuries occur (Finch *et al*., 2002; Hendricks *et al*., 2012). Coaches play a big role in player's behaviours through education. Coaches can teach correct and safe techniques, while promoting injury prevention through appropriate and positive behaviours towards injury management (Whatman *et al*., 2018).

Rugby referees have an important job to ensure that rugby teams and players abide by the laws of the game and are penalised when necessary by making the correct decisions at any point in time during a match (Reilly & Gregson, 2006; Rullang *et al*., 2017). The study conducted by Brown *et al*. (2018) found that 60% of illegal tackles were not sanctioned by on-field referees, compared to the study conducted by Kraak *et al*. (2019), where 57% of dangerous illegal ruck cleanouts were not penalised by the on-field referees in the Super Rugby Tournament. Many factors influence the decision-making accuracy of referees, such as: personality; game management; physical fitness; positioning; mechanics; knowledge and application of the law; contextual judgement; and psychological characteristics (Mascarenhas *et al*., 2005). The decision-making process of a referee is impaired by high physical and psychological demands (Tomporowski, 2003; Chang *et al*., 2012; Schmidt *et al*., 2019) causing a reduction in attention and executive function (Arnsten, 2009), which has an effect on on-field decision accuracy. Fatigue is another factor, where peripheral fatigue in the brain can result in impaired attention and altered decision-making (Rattray *et al*., 2015). Referees need to be physically fit to keep up with the high demands of the game and if the high demands decrease it can affect their decision-making accuracy (Helsen *et al*., 2019; Schmidt *et al*., 2019) and potentially lead to injuries.

Studies have shown improvements in player behaviour through coach and referee education (Gianotti *et al*., 2009) where the success of injury prevention programs were influenced by the compliance of players (Steffen *et al*., 2013) and were dependent on understanding how an injury is sustained and how to identify associated risk factors (Moore *et al*., 2015). Injury prevention is a four-step sequence: (1) identify the magnitude of the problem and describe it in terms of incidence and severity; (2) identify the risk factors and injury mechanisms; (3) introduce measures that are likely to reduce future risks and/or severity of sports injuries; and (4) assess the effectiveness of the preventative measures (Van Mechelen *et al*., 1992). This prevention model mentioned by Van Mechelen *et al.* (1992) is the most widely used model for injury prevention in sport (Engebretsen

& Bahr, 2009). Injury surveillance is an on-going process of analysis that aids in the management of injury risks associated with any given sport (Fuller & Drawer, 2004; Van Mechelen *et al*., 1992; Finch, 2006), and is the first step in designing prevention programmes (Starling *et al*., 2018). Limited injury surveillance studies were conducted at youth level (Quarrie *et al*., 2019), which is important for player safety in order to understand the risk factors because to date there is no literature available on the risk factors in youth rugby (Tucker *et al*., 2016), because the majority of literature has focused on professional rugby.

PROBLEM STATEMENT

Rugby is the most popular collision sport in the world. However, concerns have been raised regarding the safety of rugby because of the physical high impact nature of the game (Nicol *et al*., 2010). Injuries sustained in youth sport may have significant consequences for physical development and activity (Haseler *et al*., 2010). Tackles and rucks are the most common phases of play in rugby that cause the most injuries, therefore, making tackles and rucks as the most important phases to be investigated and improved to limit injuries and make the game safer (Vaz *et al*., 2010). Therefore, the surveillance of legal and illegal (including both dangerous and not dangerous) ruck cleanouts and the sanctions imposed or not imposed by rugby referees will help identify whether players are playing according to the laws of the game and whether referees are effectively enforcing the laws of the game according to World Rugby. Thus, the findings of the current study could lead to the development and implementation of further injury prevention strategies to make rugby safer for players and to improve coaching and referee education. Thus, this study can help BokSmart achieve their goal of "Vision Zero" - eliminating all serious injuries from rugby (Brown *et al*., 2017).

RESEARCH QUESTIONS, AIMS, OBJECTIVES AND HYPOTHESES

Research article 1

Research question

What is the incident rate of legal and illegal (both not dangerous and dangerous) ruck cleanouts in the Under 18 Craven Week rugby tournament?

Aim

The primary aim of the current article was to investigate the incidence and type of legal and illegal (not dangerous and dangerous) ruck cleanouts during the Under 18 Craven Week rugby tournaments between 2015 and 2019 by comparing incidence and type across cleaner technique, chronological years, match time periods, match outcome and zonal pitch locations.

Specific objectives

i. To describe the incidence of legal and illegal (both not dangerous and dangerous) ruck cleanouts during the Under 18 Craven Week rugby tournaments between 2015 and 2019, comparing across, cleaner technique, chronological years, match outcome, match time periods and zonal pitch locations.
ii. To describe the types of illegal (both not dangerous and dangerous) ruck cleanouts during the Under 18 Craven Week rugby tournaments between 2015 and 2019.

Hypotheses (H_1)

i. There will be more legal than illegal ruck cleanouts and more illegal ruck cleanouts will occur in match time periods 2 and 4 and in zones B and C.
ii. There will be more illegal not dangerous cleanouts than illegal dangerous cleanouts and more dangerous ruck cleanouts will occur during match time periods 2 and 4 and in zones B and C.
iii. Different types of illegal not dangerous ruck cleanouts including: neck rolls, not supporting own body weight, joining the ruck while in an offside position, shoulder charge, side entry, not grasping onto teammate when cleaning, cleaning player not involved in ruck and contact above oppositions shoulder.
iv. Different types of illegal dangerous ruck cleanouts including, such as: not grasping a player, shoulder charge, grasping the neck, not supporting own body weight, cleaning a player not involved in a ruck and contact above oppositions shoulder will be revealed.

Research article 2

Research question

What decisions do on-field referees make during illegal not dangerous and illegal dangerous ruck cleanouts in the Under 18 Craven Week rugby tournament?

Aim

The primary aim of this research article was to investigate the incidence, types of ruck cleanouts and sanctioning of illegal not dangerous and illegal dangerous ruck cleanouts during the Under 18 Craven Week rugby tournaments between 2015 and 2019 by comparing across chronological years, match time periods, zonal pitch locations, types of illegal cleanouts, arrival time of referee, positioning of referee at ruck, line of positioning, factors that influence of sanctioning illegal ruck cleanouts by referees and whether illegal ruck cleanouts was correctly sanctioned according to the World Rugby Law Book.

Objectives

i. To describe the incidence of illegal not dangerous and illegal dangerous ruck cleanouts sanctioned and not sanctioned by on-field referees during the Under 18 Craven Week rugby tournaments between 2015 and 2019 by comparing across chronological years, match time periods, zonal pitch locations, types of illegal cleanouts, arrival time of referee, positioning of referee at ruck, line of positioning, factors that influence of sanctioning illegal ruck cleanouts by referees and whether illegal ruck cleanouts was correctly sanctioned according to the World Rugby Law Book.

ii. To describe the different types of illegal not dangerous and illegal dangerous ruck cleanouts sanctioned and not sanctioned by on-field referees during the Under 18 Craven Week rugby tournaments between 2015 and 2019, by comparing chronological years, match time periods, zonal pitch locations, types of illegal cleanouts, arrival time of referee, positioning of referee at ruck, line of positioning and factors that influence of sanctioning illegal ruck cleanouts by referees.

Hypotheses (H1)

i. 90% of illegal not dangerous ruck cleanouts will be non-sanctioned by on-field referees, particularly during match time periods 2 and 4 and in zones B and C.

ii. Of the different illegal ruck cleanouts not sanctioned, 80% will be a shoulder charge and will mostly occur during match time periods 2 and 4 and in zones B and C.

iii. 50% of illegal dangerous ruck cleanouts will be non-sanctioned by on-field referees, particularly during match time periods 2 and 4 and in zones B and C.

iv. Of the different illegal dangerous ruck cleanouts not sanctioned, 85% will be a shoulder charge and 80% will be a neck roll.

MOTIVATION FOR THE STUDY

To date, this is the first study to investigate player behaviour and the second to investigate sanctioning. Most of the previous research focused on technical and tactical characteristics of the tackle (Davidow *et al*., 2018; Hendricks *et al*., 2018) sanctioning the tackle (Brown *et al*., 2018) and injury risk associated with the tackle (Fuller *et al*., 2008; Burger *et al*., 2014; Mathewson & Grobbelaar, 2015; Tierney & Simms, 2018; Tierney *et al*., 2018). The study conducted by Kraak *et al*. (2019) raised a notable concern, because not sanctioning illegal ruck cleanouts could result in injuries in professional rugby. The results from Kraak's study revealed that there were a total of 22 281 ruck cleanouts, with 2 111 (9%) deemed illegal. Of the 2 111 (9%) deemed illegal, 1 087 (57%) were dangerous and were not sanctioned by on-field referees. The study conducted by Mitchell & Tierney (2020), investigated the sanctioning of breakdowns during the knockout stages of the 2019 rugby world cup. They found that 37.9% of all breakdown events had at least one illegal infringement, and 79.9% of these illegal infringements were not sanctioned by the on-field referee. These statistics mentioned by Kraak *et al*. (2019) and Mitchell and Tierney (2020), represent player behaviours that needs to be investigated and improved in order to bring the incidence rate down, thereby decreasing the number of injuries. To ensure safety during rugby matches and training, specialist coaches and trainers need to teach their players the effective and safe ruck cleanout techniques. Players executing incorrect techniques lead to unnecessary illegal not dangerous and illegal dangerous ruck cleanouts and thereby increase the risk for injury. By assessing the incidence rates and types, researchers can determine which techniques the coaches need to focus on and improve, which techniques compromise the safety of players and what changes in ruck cleanout law could improve current injury prevention efforts. Players need to adhere to the laws of the game and referees need to enforce the laws to reduce the risk of injury during ruck cleanouts. Limited studies have been conducted on schoolboy rugby (Quarrie & Hopkins, 2007; Fuller *et al*., 2008; Fuller *et al*., 2009; Taylor *et al*., 2011; Haseler *et al*., 2010; Fuller *et al*., 2013; Palmer-Green *et al*., 2013; Burger *et al*., 2014), and therefore, incidence rates and injury risk factors are not well known. Therefore, further investigations are needed to improve the development of injury prevention programmes and to expand the research. The high number

of injuries at school level can have a negative effect on player welfare, lead to inactivity or players stopping rugby and changing to a different sport that has fewer injuries (Maffulli *et al*., 2010). Research also states that players at school level are more susceptible for injuries (Halstead *et al*., 2010), especially musculoskeletal injuries and concussion (Archbold *et al*., 2017), which needs to be further investigated and risk factors need to be identified because they are unclear at this level (Tucker *et al*., 2016; Archbold *et al*., 2017). Injuries at school level can result in long-term disability and a compromised quality of life later on (Maffuli *et al*., 2010). This high susceptibility rate can also be decreased through coaching correct and safe techniques at the rucks and tackle events.

Rugby is a fast paced, high injury risk sport played over a large field with one on-field referee and two assistant referees. Thus, it is easy for referees not to detect or penalise certain foul play events, particularly if referees are not properly trained or educated (Comstock & Fields, 2005). Referees need to minimize foul play to make rugby safer. Reductions in foul play can be achieved by educating referees, coaches and players on the prevalence of foul play and how it results in injury (Comstock & Fields, 2005; Sinne & Fogel, 2013). In both studies conducted by Kraak *et al*. (2019) and Mitchell and Tierney (2020), it is evident that referees are not consistent with the application of the Laws of The Game at the ruck cleanout, resulting in a high risk for injury which needs to be addressed. By investigating the number and type of legal and illegal (not dangerous and dangerous combined) ruck cleanouts and the percentage of non-sanctioned ruck cleanouts, the current research articles could help to better understand player and referee behaviour.

STRUCTURE OF THE THESIS

The thesis is presented in a research article format. Two research articles (Chapters Four and Five), were prepared according to the guidelines of the specific journals.

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

Chapter Two: Theoretical background: The chapter is included herewith, and an adapted Harvard method of reference was used in accordance with the Department of Sport Science guidelines, Stellenbosch University.

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

Chapter Four: Research Article One: An investigation into legal and illegal ruck cleanouts during elite youth rugby tournaments. This chapter is included herewith in accordance with the journal guidelines of *Journal of Sports Sciences*.

Chapter Five: Research Article Two: Sanctioning of illegal ruck cleanouts by on-field referees during elite youth rugby union tournaments. This chapter is included herewith in accordance with the journal guidelines of *Journal of Science and Medicine in Sport.*

Chapter Six: Summary, limitations, and future research. The chapter is included herewith, and the Harvard method of reference is used in accordance with the guidelines of the Department Sport Science, Stellenbosch University.

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CHAPTER TWO

THEORETICAL BACKGROUND

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

INTRODUCTION

Rugby Union (henceforth, referred to as rugby) is one of the most popular collision sports in the world (Brooks *et al*., 2005; Yeomans *et al*., 2018; Brown *et al*., 2019), with an estimated 9.1 million players in 133 rugby unions (World Rugby, 2018). Rugby exposes players to repetitive physical collisions throughout a match, which could result in injury. Regarding the safety of rugby, because of the high impact nature of the game, concerns have been raised (Nicol *et al*., 2010). In rugby, tackles and rucks are the most common phases of play that cause most injuries (Fuller *et al*., 2007a). Players are involved in 20 to 40 physical confrontations per game and wear minimal or no protective gear (Hoskins *et al*., 2006; Hendricks & Lambert, 2010). Because tackles and rucks were found to be the most important contact phases, they need to be studied and improved upon to limit injuries and make the game safer (Vaz *et al*., 2010). To date only two studies focused on ruck cleanouts and the breakdown (Kraak *et al*., 2019; Mitchell & Tierney, 2020). Most research focused on the technical and tactical characteristics of the tackle (Davidow *et al*., 2018; Hendricks *et al*., 2018), sanctioning of the tackle (Brown *et al*., 2018a) and the injury risk associated with the tackle (Fuller *et al*., 2008; Burger *et al*., 2014; Mathewson & Grobbelaar, 2015; Tierney & Simms, 2018; Tierney *et al*., 2018).

Rugby is a fast paced, high injury risk sport played over a large field with only one on-field referee assisted by two assistant referees. This could result in referees not detecting or penalising certain foul play events when not properly trained and educated (Comstock & Fields, 2005). Referees and players play a major role in the management of injuries and safety of the game through their behaviours and attitudes on the field. To make rugby safer, referees need to minimize injury risks by penalising all forms of foul play, players need to abide by the laws of the game and coaches

need to enforce this during training sessions and matches. Management of injuries and the safety of the game could be improved by educating referees, coaches, and players on the prevalence of foul play and how it results in injury (Comstock & Fields, 2005; Sinne & Fogel, 2013). Injury prevention programmes could make players, coaches, and referees aware of the injury risks involved and how to prevent them through the education of safety aspects and correcting player's skill techniques.

Injury surveillance is important to quantify and manage the risk of injury associated with a specific event, especially looking at contact events in rugby (Van Mechelen *et al.*, 1992; Fuller & Drawer, 2004; Finch, 2006). Behaviour that characterises illegal and dangerous ruck cleanouts need to be studied to improve injury prevention programs in order to decrease the number of possible injuries sustained during this phase of play. Epidemiology studies have mainly focused on elite level rugby (Finch, 2012; Williams *et al*., 2013) with limited studies conducted at school level. Injury epidemiological studies of school rugby will provide information about injury risks and trends in order to help and improve the development of injury-prevention programmes (Barden & Stokes, 2018). This chapter aims to review the available literature and to present it in the following sections: (1) rugby union; (2) ruck cleanouts; and (3) behaviour towards injury prevention.

RUGBY UNION

History and background

Rugby originated in the town of Rugby in Warwickshire, England in 1823 during a game of school football (soccer) where a young man by the name of William Webb Ellis picked up the ball during the football game and ran towards the opposition's goal line (Guttmann, 2004; World Rugby, 2015), which then became known as rugby. The first set of rugby laws was only introduced in 1845 (Corson, 2009). Because of the increasing popularity of rugby, the International Rugby Board (IRB), now known as World Rugby (WR), was established in 1886 (RFU, 2015).

Rugby is a contact sport that includes bouts of physical collision that is interspersed with intermittent high-intensity running activity (Roberts *et al*., 2008; Roberts *et al*., 2013). It is also characterised by having four main phases of play: (1) tackles; (2) rucks and mauls; (3) set pieces, such as scrums and lineouts; and (4) open-play (Kaplan *et al*., 2008). Rugby is played with a

maximum number of 15 players per team and is played for 80 minutes in total with 40 minutes per side at senior level (Quarrie & Hopkins, 2007), and 70 minutes with 35 minutes per side at school level. There are eight forward (jersey numbers 1 to 8) players characterised by being taller and heavier. Their role is to contest possession of the ball. There are also seven back (jersey numbers 9 to 15), players characterised by generally being smaller and quicker and their role is to gain field positions and score points (Quarrie *et al*., 2007). A team is allowed a maximum of eight replacements (at professional level) and seven at amateur level. These replacements are only allowed to go onto the field when the ball is dead and/or with permission from the referee (World Rugby, 2020).

TABLE 2.1: **JERSEY NUMBER AND POSITIONAL GROUPS**

Jersey numbers	**Primary positional group: Forwards**	**Secondary positional group**
1	Loose head prop	Tight five
2	Hooker	Tight five
3	Tighthead prop	Tight five
4	Lock	Locks
5	Lock	Locks
6	Blindside – flanker	Loose forwards
7	Open side – flanker	Loose forwards
8	Number 8	Loose forwards
Jersey numbers	**Primary positional group: Backs**	**Secondary positional group**
9	Scrum-half	Inside backs
10	Fly-half	Inside backs
11	Left wing	Outside backs
12	Inside centre	Inside backs
13	Outside centre	Outside backs
14	Right wing	Outside backs
15	Full back	Outside backs

Professionalism in rugby was first introduced in 1995 (Quarrie *et al*., 2007), which has led to an increased incidence of injuries (Posthumus & Viljoen, 2008) because of the increased demands on training and competition (Sedeaud *et al*., 2013). To meet these demands players needed to become bigger faster and stronger at junior and senior levels (Olds, 2001; Sedeaud *et al*., 2012, 2013; Lombard *et al*., 2015). This was achieved through increased training, nutritional and conditioning programs (Olds, 2001; Sedeaud *et al.*, 2013; Lombard *et al*., 2015). The number of tackles and

ruck events have also increased over time because of professionalism (Quarrie & Hopkins, 2007). For example, Quarrie (2009) observed that there was an increase in the number of rucks (160 ± 24) and tackles (270 ± 25) since the advent of professionalism in 1995 (Kraak, 2015).

Laws of the game

The laws of the game provide a framework that players, coaches and referees must adhere to, resulting in a game that is safer and more enjoyable to play and watch (Murray *et al*., 2014). WRs responsibility is to provide laws that lead to safe, enjoyable and entertaining rugby events (Murray *et al*., 2014). Law changes are implemented in response to player behaviour, safety and to increase participation and enjoyment, promote continuity of the game, technological advancement, commercial pressures and to retain game integrity and development (Eaves *et al*., 2008; Kraak & Welman, 2014).

Foul play includes, but is not limited to obstruction, misconduct, repeated infringements and dangerous and unfair play. The sanction for foul play is a red or yellow card according to the law book (WR, 2020). Dangerous play can occur anytime during the game and includes, but is not limited to late or early tackles, physical or verbal abuse, tackling players not in possession of the ball, not grasping or lifting a player off the ground during the tackle. The minimum sanction for dangerous play is a penalty kick for the opposition but can also results in a penalty kick with a yellow or a red card (WR, 2020).

Under 18 school rugby has slight law variations in comparison to senior rugby (Boucher, 2017). The duration of the match is 70 minutes (35 minutes per half), and no extra-time is allowed. A team is not allowed to push the scrum more than 1.5 metres, may not keep the ball in the scrum once it is heeled and controlled at the base of the scrum and may not intentionally wheel the scrum. Fewer than eight players are allowed in the scrum if a team is not able to field a complete team because of a player being sent off the field or injured, and therefore, result in an uncontested scrum. When one team cannot form a scrum with eight players, the other team must reduce their scrum accordingly, with a minimum of five required in a scrum (WR, 2020).

Craven week rugby tournament

The Under 18 Craven Week rugby tournament is an annual South African elite school rugby tournament organised by the South African Rugby Union (SARU), which comprise of the top Under 18 rugby players in the country. The SARU hosts four annual merit-based tournaments namely: Under 13 Craven Week, Under 16 Grant Khomo, Under 18 Academy Week and Under 18 Craven Week (Brown *et al*., 2012; Burger *et al*., 2014). The Under 18 Craven Week has been rated as one of the top school rugby tournaments in the world (Nienaber, 2013). The tournament helps to identify and develop rugby talent in South Africa and is supported by several Springboks having played in this tournament (Colquhoun *et al*., 2009). On average 20 teams participate in the Craven Week tournament with two invitational teams from Namibia and Zimbabwe (Brown *et al*., 2012). However, in 2018 and 2019 these two teams were excluded from the U18 Craven Week and only included in the Academy Week. Referees are ranked during this tournament, and therefore, it is also used to develop referees (Boucher, 2017).

Injury epidemiology in rugby

Rugby has the highest injury incidences (81 injuries per 1 000 player hours) compared with other team sports (Holtzhausen *et al*., 2006; Williams *et al*., 2013; Burger *et al*., 2016), such as Australian football (39 injuries per 1 000 player hours) (Ekegren *et al*., 2015), ice hockey (52.1 per 1 000 player hours) (Tuominen *et al*., 2015), and soccer (32.8 per 1 000 player hours) (Stubbe *et al*., 2015). High injury incidences in rugby occur because of the contact nature where players are required to physically contest for ball possession, resulting in frequent collisions (Hendricks & Lamberts, 2010; McIntosh *et al*., 2010). Injury incidence is the average number of injuries occurring in 1 000 hour match-play exposure (Williams *et al*., 2013):

$$Injury\ incidence = \frac{number\ of\ injuries}{number\ of\ matches \times number\ of\ players \times match\ duration} \times 1000$$

In senior professional rugby match injuries occur at a rate of 94 injuries per 1 000 player exposure hours during the 2019 Currie Cup Tournament (Starling *et al*., 2019). Comparatively, at the 2019 South African Rugby Union (SARU) Youth Week Tournaments, the under 18 Craven Week and the under 18 Academy Week, reported 21 injuries and 25 injuries per 1 000 player exposure hours, respectively (Paul *et al*., 2020). Based on the findings from the relatively limited number of studies conducted on school rugby the injury incidence rate seems to be less in school rugby (Quarrie &

Hopkins, 2007; Fuller *et al*., 2008; Fuller *et al*., 2009; Haseler *et al*., 2010; Taylor *et al*., 2011; Fuller *et al*., 2013; Palmer-Green *et al*., 2013; Burger *et al*., 2014), than in professional rugby (Gabb *et al*., 2015).

The majority of the injuries in rugby occur during contact events (Schneiders *et al*., 2009; Roberts *et al*., 2013). The contact events that cause injury at senior and elite levels in South African rugby are tackles (24 to 58%), rucks (6 to 17%), mauls (12 to 16%), collisions (8 to 9%) and scrums (2 to 8%) (Fuller *et al*., 2007a; Posthumus & Viljoen, 2008; Hendricks & Lambert, 2010; Roberts *et al*., 2015), with tackles occurring the most frequently and causing the most injuries and days lost through injury (Fuller *et al*., 2007a; Roberts *et al*., 2015). In South African school rugby tackles result in the majority of injuries, where ball carriers have an injury incidence of 11.3 injuries per 1 000 player exposure hours and tacklers 7 injuries per 1 000 player exposure hours. Ruck injuries are 4.4 injuries per player exposure hours (Sewry *et al*., 2019). During a professional rugby match an average of 165 tackles and 100 rucks occur (Hendricks *et al*., 2018). However, the greatest propensity for severe injury is caused by collision tackles (shoulder charges) and scrums at professional rugby. In South African rugby the incidence of catastrophic injuries (any neck, head, spine or brain injury) that are deemed as life threatening is 2.1 injuries per 100 000 and the incidence for spinal cord injuries is 1.0 per 100 000 players (Brown *et al*., 2013).

Tackles that place both the tackler and the ball carrier at risk of injury, have the greatest propensity to cause injury across all competitive levels and ages of rugby (Schneiders *et al.*, 2009; Hendricks & Lambert, 2010; Taylor *et al*., 2011; Sarembock, 2014; Schwellnus *et al.*, 2014; Whitehouse *et al*., 2016; Willigenburg *et al.*, 2016). Illegal tackles are less likely to occur than legal tackles, but are 70% more likely to cause injury (Fuller *et al*., 2007a). Concussion is one of the most common injuries that occurs in rugby, with the majority of concussions occurring during tackles, resulting in an incidence of 4.1 to 8.9 injuries per 1 000 player hours (Kemp *et al*., 2008; Moore *et al*., 2015; Cross *et al*., 2016). A study conducted by Brown *et al*. (2018a) during the 2011 to 2015 Under 18 Craven Week rugby tournament found that out of a total of 12 216 tackles, 12 103 were legal and 113 illegal. Of the 113 illegal tackles, the on-field referee did not sanction 59% (67 out of 113). The majority of the illegal tackles occurred in quarters two (29%) and four (29%), compared to quarters one (21%) and three (21%) of match-play (Brown *et al*., 2018a).

In school rugby, tackles are responsible for 60% of all injuries, including 62% of concussions and 50% of spinal cord injuries (Burger *et al*., 2014; Hendricks *et al*., 2014; McFie *et al*., 2016). It is clear that concussion occurs the most in comparison to other injuries and that an urgent need exists to focus on strategies to decrease this risk. In order to decrease the number of tackle injuries, coaches need to develop players technical abilities to contest tackle events safely and correctly (Hendricks *et al*., 2012; Burger *et al*., 2016; Hendricks *et al*., 2016) and focus on techniques, which can be developed through training (Hendricks & Lambert, 2010; Hendricks *et al*., 2012). Incorrect techniques are a major risk factor for injury (Burger *et al*., 2016). Indeed, research has shown that player's ability to contest the tackle is a prerequisite for safe and successful rugby (Hendricks *et al*., 2017a).

Risk of injury increases with age and the competitive level because of greater speed, competitiveness, weight, height and foul play (Bleakley *et al*., 2011; Brown *et al*., 2012; Hendricks *et al*., 2012). According to Boucher (2017), the lower limb region has the highest injury incidence compared with the upper limb region. Injuries at school level can have a number of short and long-term health effects, which can have a negative impact on player welfare and team success (Williams *et al*., 2016). These health effects can lead to some players withdrawing from playing rugby or joining another sport (Maffulli *et al*., 2010). Two studies have stated that a big injury risk for school players is school-age related characteristics, namely: body composition; bone structure; psychological maturity; strength; and muscle growth (Halstead *et al*., 2010; Patel *et al*., 2017). The assessment of injury risks at school level is importance because there is a greater susceptibility for injuries, especially concussion (Halstead *et al*., 2010). The real cause behind the high injury risk at school level is yet unclear (Tucker *et al*., 2016; Archbold *et al*., 2017), which needs further investigation because the majority of epidemiological and surveillance studies have focused on professional players, and therefore, the risk factors at school level are not known (Tucker *et al*., 2016).

Table 2.2 represents the results from the study by Palmer-Green *et al.* (2013) conducted among English Youth Academy and Schools Rugby players aged 16 to 18 years old. From the results, it is clear that contact events caused the most injuries, with tackles presenting the highest percentage of injury in both academy and school rugby levels. Being tackled represented 30 and 32% of

injuries in the academy and school levels respectively, whereas tackling represented 21 and 25% of the injuries in academy and school levels respectively. Rucks and mauls were the next area of concern, with the percentage of injuries at 14 and 16% in academy and school levels, respectively.

TABLE 2.2: **INJURY EVENTS EXPRESSED AS PERCENTAGES OF INJURIES, INCIDENCE AND SEVERITY FOR ACADEMIES AND SCHOOLS** (Palmer-Green *et al*., 2013)

	Academy level			School level		
Injury event	% of Injuries	Incidence, n (95% CI)	Severity, d (median)	% of Injuries	Incidence, n (95% CI)	Severity, d (median)
Collision	6	3 (1 - 5)	10 (5)	4	1 (0 - 3)	32 (20)
Ruck/Maul	14	6 (3 - 9)	27 (20)	16	5 (3 - 8)	15 (7)
Scrum	3	1 (0 - 2)	30 (27)	7	2 (1 - 4)	30 (8)
Tackled	30	12 (8 - 17)	36 (21)	32	10 (7 - 13)	34 (14)
Tackling	21	9 (5 - 13)	36 (18)	25	8 (5 - 11)	33 (20)
Other contact	3	1 (0 - 3)	18 (24)	3	1 (0 - 2)	36 (48)
All contact	77	32 (25 - 39)	32 (20)	87	27 (22 - 32)	30 (16)
All noncontact	23	10 (6 - 14)	30 (20)	13	4 (2 - 6)	26 (11)

Table 2.3 represents the results from the study by Marsh (2018) conducted during the 2011 to 2014 Youth Week tournaments in South Africa. The ruck follows on the tackle as cause of injury, which is similar to the findings reported by Palmer-Green *et al*. (2013). In Table 2.3, the tackle resulted in 55% of the injuries over the four-year period, the tackler resulted in 37% of the injuries, the ball carrier 18% and the ruck resulted in 20% of the injuries.

TABLE 2.3: **PROPORTION OF INJURY INCIDENTS PER YEAR AT SOUTH AFRICAN RUGBY UNION UNDER 18 CRAVEN WEEK BETWEEN 2011 AND 2014** (Marsh, 2018)

Injury event	2011		2012		2013		2014		Overall	
	TL	ALL	TL	ALL	TL	ALL	TL	ALL	TL	ALL
Tackle	57	59	65	60	55	50	49	52	57	55
Tackler	29	34	38	38	42	35	41	41	37	37
Ball-carrier	28	25	27	22	13	15	8	11	20	18
Maul	1	1	0	1	2	1	1	4	1	2
Ruck	21	23	16	19	8	24	24	18	18	20
Scrum	4	4	1	2	4	5	3	3	3	3
Line-out	0	1	3	1	2	1	1	1	1	1
Open play	9	6	6	6	21	11	6	7	10	8
Running/kicking	2	3	4	5	2	3	12	10	5	6
Unsure/NA	5	5	5	6	6	4	5	5	5	5
Total injuries	92	189	79	247	52	176	80	263	303	875
Injuries per match	0.7	1.4	0.6	1.8	0.4	1.3	0.6	1.9	0.6	1.8

Note: * *'Time-loss injuries'* (TL), Over all injuries (ALL)

The main findings depicted in the two tables were that the two main contact events causing the most injuries during school rugby, were the tackle and ruck. This shows that both these events need to be considered when trying to reduce the number of injuries in school rugby and when developing injury prevention programmes.

Injury management

According to Van Mechelen *et al*. (1992), the first step to injury prevention is surveillance. By having surveillance of illegal and dangerous ruck cleanouts from player, coach and referee perspectives will assist BokSmart™ and SARU to create and implement new injury prevention strategies. WR's strategic plan for 2016 to 2020 has a big emphasis on injury surveillance focusing

on player welfare and safety of the game (WR, 2016a). Risk factors identified through injury surveillance are resolved through specific interventions (Leachy *et al*., 2019). There are four steps in the Van Mechelen injury prevention model, namely: (1) establish the extent of the problem; (2) establish the aetiology and mechanism of the injury; (3) introduce preventative measures; and (4) evaluate the effectiveness of the prevention strategies by repeating step one (Van Mechelen *et al*., 1992). There are numerous injury diagnosis formats used in rugby, namely: The Orchards Sports Injury Classification (OSICS) (Brooks *et al*., 2005); the International Classification of Disease (Garraway *et al*., 2000); diagnosis that is defined by anatomical location and pathology (Targett, 1998; Bathgate *et al*., 2002); and the World Rugby injury surveillance statement (Fuller *et al*., 2007b). Some of the research that has been completed on injury surveillance and mechanisms has used the OSICS coding system (Palmer-Green *et al*., 2013; Roberts *et al*., 2014; Singh *et al*., 2016), or the World Rugby injury surveillance consensus statement (Fuller *et al*., 2007b; Tee *et al*., 2018; Viviers *et al*., 2018). In the study conducted by Fuller *et al.* (2007b), the WR's consensus statement for injuries was introduced for studies to be able to compare results on injuries because there was no clear definition for injury before this. Video analysis of injuries provides valuable information on the playing situation and player movement patterns, which can be used to create and refine injury prevention strategies (Krosshaug & Verhagen, 2010).

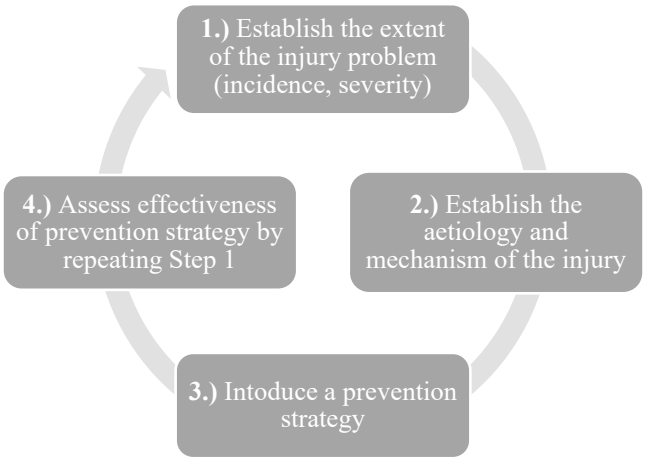

FIGURE 2.1: **THE VAN MECHELEN MODEL: INJURY PREVENTION STEPS** (Adapted from Van Mechelen, 1992).

Rugby safety programmes are implemented to educate coaches, players and referees on the prevalence of injuries in rugby and how to potentially overcome them to make the game as safe as possible for all involved (Viljoen & Patricios, 2012). Safety in sport, especially with rugby being a sport that has a high risk for injury, is one of the most important requirements to allow for continued participation (Verhagen *et al*., 2010). There are six key injury prevention programmes internationally, namely: (1) New Zealand's RugbySmart; (2) Australia's Smart Rugby; (3) the RFU's 'Rugby Safe'; (4) World Rugby's 'Rugby Ready'; (5) Argentina's 'Rugby Seguro'; and (6) South Africa's 'BokSmart™'. RugbySmart and BokSmart™ are the only two prevention models that have completed the four steps of the Van Mechelen injury prevention model and with studies completed on the effectiveness of RugbySmart (Quarrie *et al*., 2007; Gianotti *et al*., 2009; Brown *et al*., 2014). RugbySmart originated in New Zealand in 2001 and was associated with a reduction in scrum-related spinal injuries (Quarrie *et al*., 2007). RugbySmart was designed to reduce the number and severity of injuries in community rugby by providing evidence-based information about injury risks and injury prevention strategies to coaches and referees (Gianotti *et al*., 2009). Application of injury prevention programmes are challenging because of the expectation of a researcher for positive behavioural changes and compliance to the programme (Viljoen & Patricios, 2012).

SARU developed BokSmart™ in 2009, which was based on, and adapted from the RugbySmarts concept. The main goal of BokSmart™ is aimed at reducing the number of injuries, especially catastrophic concussions, head/neck and spinal cord injuries. It is compulsory for all coaches and referees in South Africa to attend the BokSmart™ courses biennially (Gianotti *et al*., 2009; Viljoen & Patricios, 2012). Players and coach's knowledge, attitudes and behaviours have been identified as risk factors for injury in rugby (Finch *et al.*, 2001; Finch *et al*., 2002; Hendricks *et al*., 2012). Educating rugby coaches and referees has resulted in improved player injury prevention behaviour (Gianotti *et al*., 2009), and a reduction of injury rates (Brown *et al*., 2018b). According to Lund and Aarø (2004), there has been an assumption that knowledge will modify attitude and change a person's behaviour. This pathway has demonstrated to be effective in national injury prevention initiatives (Cook *et al.*, 2003; Quarrie *et al*., 2007; Australian Rugby Union, 2008; Gianotti *et al.*, 2009; Viljoen & Patricios, 2012). Knowledge gained by the coaches and referees will filter down to the players, which will in turn lead to a decrease in injury risks, better attitudes and behaviours

towards the safety aspects of the game (Quarrie *et al.*, 2007; Gianotti *et al.*, 2009; Viljoen & Patricios, 2012). According to Steffen *et al*. (2013), the success of any injury prevention programme relies on the compliance of players. With the correct training of coaches and referees, this will ensure better adherence to injury prevention programmes (McKay *et al*., 2014). Performance analysis can be used as a tool to assess the effectiveness of injury prevention programmes, determine player behaviour and assist medical staff and referees with decision-making (Hendricks *et al*., 2020).

Video-based performance analysis

Video analysis is a branch of performance analysis, which merges biomechanical methods and notational analysis (Hughes & Bartlett, 2002; Glazier, 2010). Video analysis uses systematic observation and interprets videos to improve objectivity (McGarry *et al*., 2013). Match footage is analysed according to a set of performance indicators (PI's) and operational definitions to identify and describe player and team actions (Borrie *et al*., 2002; Mellalieu *et al*., 2008) in relation to specific performance and injury outcomes (Vilar *et al*., 2012). A PI is a selection of variables that aim to define performance behaviour and should relate to successful performance or outcomes (O'Donoghue, 2010). PI's can be beneficial if they are clearly defined (Hughes *et al*., 2012; Bremner *et al*., 2013), reliable and validated against successful and unsuccessful outcomes of games (Bremner *et al*., 2013). PI's provide an understanding of game behaviour by explaining the game outcome (McGarry, 2009). There are a number of methods for the selection of PI's, namely: using a panel of specialists (Choi, 2008); regression analysis that deals with outcome indicators (Choi *et al*., 2006a); neural networks (Choi *et al*., 2006a); and inferential statistical tests that identify the PI's, which distinguish between winning and losing performances within matches (Choi *et al*., 2006b; Csataljay *et al*., 2008; Hawkins & Choi, 2008). There is no gold-standard for the selection of PI's (O'Donoghue, 2010). The methods mentioned above are used as guidance.

Computerised software, such as Nacsport is needed to code specific PI's according to their operational definitions. Reliability is the extent to which the event codes display what happened in a match (James *et al*., 2007). Reliability is the extent to which the measuring process can be used to produce consistent results when repeating the procedure (Weiner, 2007). Three sources of error appear in performance analysis: (1) operational error (observer presses wrong button); (2)

observational error (observer fails to code an event); and (3) definitional error (event labelled incorrectly as defined) (James *et al*., 2002). When assessing reliability, it is suggested that a gold-standard is created for coding and to perform inter- and intra-analyst reliability to determine the error rates (James *et al*., 2007).

Validity of individual PI's is dependent on its relevance and reliability (Morrow *et al*., 2005) and cannot be valid if it is not reliable. For a PI to be valid it needs to represent an important aspect of sport performance. The validity of PI's can be determined by a panel of specialists through interviews and reviewing coaching and performance analysis literature related to the topic of interest (O'Donoghue, 2010). During the interviews, the panel of specialists will discuss the variables that they think are most important for the area of interest and then review video clips to identify the specific behaviours of interest (O'Donoghue, 2010). Quantitative methods, such as multiple regression techniques can also be used to determine the validity of PI's. A multiple regression technique identifies each PI's relative contribution in predicting the chosen outcome indicator (Choi *et al*., 2006b).

Video-based performance analysis has been used to investigate the differences in playing positions between individuals and teams (Eaves & Hughes, 2003; Eaves *et al*., 2005; James *et al*., 2005; Prim *et al*., 2006), changes in team formats (Jones *et al*., 2008), and successful performances (Jones *et al*., 2004). The study conducted by Francis and Jones (2014) investigated elite rugby players perceptions of performance analysis and found that players believed that video feedback improved their ability and knowledge of the game. The players saw video feedback as a learning tool where they could view areas that need improving, as well as observe their mistakes and missed opportunities during the game. Videos allows players to see the whole picture from an objective perspective and can assist players with personal reflection, motivation and increase players confidence (Bower *et al*., 2011; Francis & Jones, 2014). Players raised the difficulty level of tasks after positive feedback because of an increase in self-confidence, resulting in improved performance under pressure (Krenn *et al*., 2013).

Another advantage and use of video-based performance analysis is to create performance profiles, which are created through a collection of PI's describing the performance as a whole (O'

Donoghue, 2010). Performance profiles are also useful in describing individual and team patterns (Vaz *et al*., 2010) and can be displayed in three ways: (1) single performance outcome; (2) typical outcome; and (3) performance process (Butterworth *et al*., 2013). A single performance profile that is based on the outcome and process is an objective representation of the player using PI's (Butterworth *et al*., 2013). These profiles can be used to highlight areas that need focusing on in order to improve future performance. Performance profiles are developed by collecting frequencies of PI's that show predictions of future performance (Hughes *et al*., 2001; Bracewell, 2003). Intra-positional variability in performance profiles was used in the study conducted by James *et al*. (2005). They found that it was not necessary to have more than one profile per playing position in rugby because of the different playing styles within each position, which are all effective for the team. Therefore, a general profile can be created per playing position indicating the strengths and weaknesses (James *et al*., 2005).

Using video-based performance analysis in rugby allows coaches and players to assess contact techniques and decision-making based on objective data, which helps to identify, diagnose and correct technical and tactical problem areas (O'Donoghue, 2006; Laird & Waters, 2008; Wright *et al*., 2012; Sarmento *et al*., 2015), and improve players performance and team tactics to gain a competitive edge over their opponents (Vahed *et al*., 2016). Video analysis can also be used for injury surveillance because it provides detailed information for the aetiology of injury events, as well as an understanding of injury mechanisms and risk factors (Bahr & Krosshaug, 2005; Krosshaug *et al*., 2005). Indeed, video analysis has been used for injury epidemiology studies in numerous sports including rugby union (Quarrie & Hopkins, 2008; Fuller *et al*., 2010; McIntosh *et al*., 2010), football (Andersen *et al*., 2003), ice hockey (Hutchison *et al*., 2015), basketball (Krosshaug *et al*., 2007), handball (Olsen *et al*., 2004) and lacrosse (Lincoln *et al*., 2013). It has become a very popular tool to use for injury management (Borrie *et al*., 2002; Mellalieu *et al*., 2008). Video analysis can also be used to assess how effective an injury prevention intervention is (Hendricks *et al*., 2020).

THE RUCK CLEANOUT

Definition

The ruck in rugby presents the second highest number of injuries after the tackle (Williams *et al*., 2013; Roberts *et al*., 2015). The ruck is defined as a phase of play where two players, one from each team, are on their feet and in physical contact close to the ball (World Rugby, 2020). The main purpose for this phase of play is to maintain possession and/or gain territory (Hapeta, 2007). Formation of a ruck occurs directly after a tackle event where a ball carrier has gone to ground with the ball and there are one or more players from each team that are in close contact around the ball (Stewart, 1987). Players involved in the ruck are not allowed to place their heads and shoulders lower than their hips (World Rugby, 2020). The laws of rugby state that once the ball carrier has been tackled and brought to ground the player needs to place or let go of the ball and is only allowed to play the ball once they have returned to their feet. The same laws apply to the tackler. Many studies have focused on the tackle and not the ruck or cleanout event (Fuller *et al*., 2008; Burger *et al*., 2014; Matthewson & Grobbelaar, 2015; Brown *et al*., 2018a; Davidow *et al*., 2018; Hendricks *et al*., 2018; Tierney & Simms, 2018; Tierney *et al*., 2018), which is also responsible for injury if incorrect techniques are used and if the referee does not sanction these illegal ruck cleanouts. A cleanout occurs during a ruck when the player without the ball clears the opposition off the ball to prevent a turnover. A study by Kraak and Welman (2014) reveal that there were 1 479 rucks at an average of 98.6 rucks per match during the 2010 Six Nations Championship. They also found that on average, 3.6 ± 1.0 players were involved in a ruck. Kraak and Welman (2014) found that the majority of rucks occurred in zone B (attacking area between the 22m area and halfway line) of the field (f=718; 48.5%), compared with zone A (attacking area between the 22m area and try line) (f=320; 21.6%), zone C (defence area between the 22m area and halfway line) (f=377; 25.5%), and zone D (defence area between the 22m area and try line) (f=64; 4.3%). Van Rooyen *et al*. (2010) found that 67% of rucks occurred in the attacking half of the field (zones A and B) compared with 33% occurring in the defensive half (zones C and D) during the 2007 Rugby World Cup. In addition, 66% of rucks were formed in zones B and C, 27% in zone A and 7% in zone D. Finally, the top three teams in this Championship set up less rucks compared with the bottom three teams (Kraak & Welman, 2014).

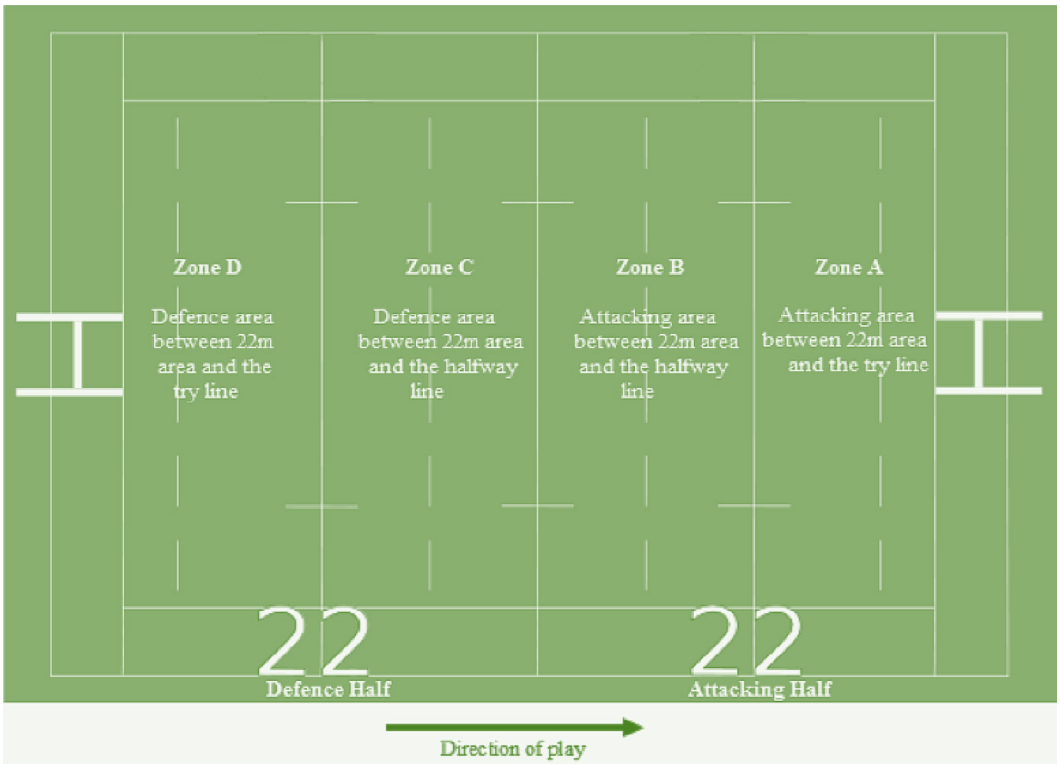

FIGURE 2.2: **ZONES FOR LOCATION OF RUCKS** (Adapted from Van Rooyen *et al*., 2010; Kraak & Welman, 2014).

Laws of the ruck

Law 15 in the 2020 World Rugby Law book represents the ruck. A ruck is formed when there is at least one player from each team that is in contact, on their feet and the ball is on the ground. Once a ruck has formed, no players can handle the ball and players are only allowed to play the ball with their feet. When players join a ruck, they need to be on their feet and join from behind their offside line. Players are required to bind or grasp onto a teammate or opposition player. During a ruck, possession of the ball is won by rucking or cleaning the opposition off the ball. During the ruck, there is a cleanout action with the purpose of retaining possession for the attacking team or trying to regain possession of the ball for the defending team. The players arriving at the ruck implement this action. There are specific ruck cleanout techniques that are perceived as illegal and dangerous according to the 2020 WR Laws of the Game. The illegal ruck cleanout types according to the 2020 WR Laws of the Game, law 9.20 and 15.5 - 15.9, include: (1) neck roll; (2) shoulder charge; (3) contact above the shoulder of an opposition player; (4) side entry; (5) not grasping or binding onto a team mate when cleaning; (6) not supporting own body weight (at all

stages during the ruck, players must have their heads and shoulders no lower than their hips); (7) cleaning out a player not involved in the ruck; and (8) joining the ruck from an offside position (WR, 2020). The minimum sanction for these infringements is a penalty kick for the opposition, penalty kick and yellow card, or a penalty kick and a red card. Not all of the illegal ruck cleanouts are deemed dangerous (Kraak *et al*., 2019). A ruck cleanout is deemed dangerous if it could lead to possible injury (World Rugby, 2020). Foul play (Law 9, WR Law of the Game) and incorrect technique during the ruck cleanout is a prerequisite for injuries (Brown *et al*., 2014). Actions need to be taken against players who commit foul play by being warned, temporarily (yellow card) suspended, or sent off the field (red card).

Players

Physical fatigue reduces player's technical contact ability (Gabbett, 2008; Burger *et al*., 2016) and mental fatigue affects contact technique in rugby (Smith *et al*., 2016), making players more at risk for injury. The ruck is considered a highly exhausting event, which could affect player's decision-making abilities because cognitive skills are impaired under physical fatigue (Deutsch *et al*., 2007; Lorains *et al*., 2013). Poor levels of player conditioning will also lead to a reduction in tackle technique proficiency, which could result in an increased risk for injury (Hendricks *et al*., 2012). During the ruck event, it is important for players to know their roles. In the attack position the role of first arriving player is to clear the tackler (1st defender), away from the ball carrier, the second players role is to maintain possession and to clear any other arriving defenders off the ball and the third or fourth arriving players role is to support the second arriving player. One player, usually the scrumhalf, takes the role of delegating where he/she is the main decision-maker that direct the attacking players (International Rugby Board, 2011, Kraak & Welman, 2014). During a ruck playe`rs need to make strategic decisions under uncertainty. The decision making includes: goal formation; identification of problems; alternatives generation; and evaluation and selection (Schwenk, 1984). In the study conducted by Kraak and Welman (2014) the results showed that the top teams formed 10% less rucks, which shows that the bottom teams play is affected by fatigue, skill level, technique, and decision-making ability.

The study conducted by Kraak *et al*. (2019: 4-5) revealed that there was a total of 22 281 ruck cleanouts, with 9% (2 111 out of 22 281) being illegal. The attacking team was responsible for

90% (1 895 out of 2 111) of the total number of illegal ruck cleanouts with an average of 16 per match. Cleaner one was responsible for 67% (1 450 out of 2 111) of the total number of illegal ruck cleanouts in both attacking and defending teams. Of the illegal cleanouts, 57% (f=1 087 out of 2 111) were deemed dangerous and not sanctioned by the on-field referee with the majority being "*shoulder charges*" (f=280), "*neck rolls*" (f=100), and "*contacts above shoulder*" (f=201) (Kraak *et al*., 2019: 4-5). The illegal and dangerous ruck cleanouts occurred at a rate of 9% and 5% respectively. The above-mentioned statistics represents player behaviour, which needs to be addressed because there is a high risk of injury that needs to be managed through improvement of technique. Contact skill training programmes in rugby needs to be developed for players to practise safe ruck techniques during training (Hendricks *et al*., 2017b). Therefore, improving ruck technique will result in an improvement in performance and safety (Den Hollander *et al*., 2019), which can be developed during training (Hendricks *et al*., 2017b).

Referees

Recently, the study conducted by Mitchell & Tierney (2020) investigated the sanctioning at the breakdown during the knockout stages of the 2019 Rugby World Cup. These researchers revealed that 79.9% of illegal infringements were not sanctioned by the on-field referee. There was one more study conducted on the sanctioning at the ruck cleanout by Kraak *et al*. (2019) where they found that the on-field referee did not sanction 93% of all illegal ruck cleanouts according to the WR Laws of The Game. The only other study conducted on the sanctioning by the on-field referee was conducted by Brown *et al*. (2018a), which investigated the sanctioning of the tackle and not the ruck event. These researchers found that the on-field referee did not sanction 59% of all illegal tackles at the South African Under 18 Craven Week rugby tournament during 2011 and 2015. With referees, not sanctioning appropriately could lead to an increase in injury risk because illegal and foul play could potentially be dangerous for all players involved.

Referees play a major role in a match because they need to ensure safety and fair play, while upholding the laws of the game (Helsen & Bultynck, 2004) to prevent injuries by sanctioning all forms of illegal, dangerous, and foul play (Burger *et al*., 2017). According to Kaplan *et al*. (2008), foul play results in 9% of all the injuries in professional rugby. Referees have a responsibility to maintain the flow and control of the game and ensure fair play according to the laws, while performing optimally in a dynamic and tumultuous environment (Mascarenhas *et al*., 2005; Kraak

et al., 2011; WR, 2016b). To have an effective performance as a referee there are five key areas: knowledge and application of the laws, contextual judgement, personality and management skills, fitness, positioning and mechanics, and psychological characteristics of excellence (Mascarenhas *et al*., 2005a). A referee needs to have good management skills on the field as their behavioural responses can affect players psychological state (Bar-Eli *et al*., 1995) and incidence of injury (Gilis *et al*., 2006). Referees often rely on judgmental heuristics to make quick decisions under time constraints (Mascarenhas *et al*., 2006; Plessner & Haar, 2006). Decision-making is a facet of the perceptual-cognitive process representing perceptual and cognitive skills including vision, attention, creative thinking and memory (Renshaw *et al*., 2019). Perceptual-cognitive process is the ability to identify and process environmental information and integrate this information with pre-existing knowledge and motor capabilities to select and execute the appropriate actions (Martenuik, 1976). An important aspect of decision-making for a referee is to know where and when to look and have the ability to process relevant information, while ignoring irrelevant information (Williams *et al*., 1999). When a referee is unable to anticipate the upcoming event and retrieve an appropriate action from memory, the decision will be delayed and therefore less reliable (Helsen & Bulltynck, 2004; Mallo *et al*., 2012). Gaze behaviour describes the visual aspect of decision-making as a searching strategy that enables the processing of environmental information (Abernethy, 1987; Goulet *et al*., 1989). Examining gaze behaviour can improve performance by allowing better information processing (Hüttermann *et al*., 2018). Gaze behaviours differ based on the task's characteristics with experts using strategies with more fixations for shorter durations during relatively dynamic tasks, such as with refereeing a rugby match and fewer fixations of a longer duration during static tasks (Gegenfurtner *et al*., 2011). Non-experts have increased fixations resulting in key cues being missed leading to incorrect decisions (Mann *et al*., 2007). Quiet eye is a gaze behaviour occurring before the final movement of a task with the offset occurring when the gaze deviates off the object. This is seen as one of the key determining factors associated with expert decision-making in sport. (Vickers, 2007; Causer *et al*., 2011).

Officiating is a stressful task that is influenced by one's self-efficacy (Bandura, 1997) and has the potential to negatively affect mental health, attentional focus and performance which could lead to dropout (Taylor *et al*., 1990; Goldsmith & Williams, 1992; Guillen & Bara, 2004). An important characteristic of a successful referee is being able to cope in a stressful situation with the

psychological demands of the game (Mascarenhas *et al*., 2004). Referees that fail to cope with the stressors results in inaccurate decision-making (Anshel *et al*., 2014). Referees use different coping strategies to deal with the stressors encountered. Emotion-focused coping strategies focus on managing the emotions that a referee experiences because of a stressor and problem-focused coping strategies actively deals and alters the stressor (Wolfson & Neave, 2007; Mathers & Brodie, 2011). Both of these coping strategies aims at helping referees to manage the stressors they encounter during a match. Self-efficacy in referees is the level of confidence they have to perform successfully (Guillen & Feltz, 2011). According to Guillen and Feltz (2011), referees with high efficacy will be more accurate in decision-making, have better performance, be respectful towards coaches and players and manage stress well.

Video replay can assist referees to make more accurate decisions (Mascarenhas *et al*., 2005b). According to the study conducted by Elsworthy *et al*. (2014), video-based assessments are valid for examining the decision-making performance of referees bearing in mind that they do not replicate physical, physiological and psychological aspects of an actual match environment. There are many factors that can influence the decision-making of the referee, which can include, but is not limited to obstructed view and distance from play (Mallo *et al*., 2012), movement speed (Oudejans *et al*., 2005) and changes in central nervous system arousal (Chmura & Nazar, 2010). The ruck is a complex event with multiple players in a confined area competing for the ball over a short period of time, making this event very difficult for referees to make accurate and consistent calls (Mascarenhas *et al*., 2005b). Another factor that affects the decision-making of the referee during a ruck is the various skill levels of the arriving players because this will determine the outcome of the ruck (Wheeler *et al*., 2013). Using video replay can assist officials to make more accurate decisions (Mascarenhas *et al*., 2005b). According to the study conducted by Elsworthy *et al*. (2014), video-based assessments are valid for examining the decision-making performance of referees bearing in mind that they do not replicate physical, physiological, and psychological aspects of an actual match environment.

Fitness levels of referees play a big role on the outcome of the game (Burger, 2010) and high levels of fitness are a prerequisite for referees at any competitive level to meet the physiological demands of the game and to ensure accurate interpretation of the laws of the game (Müniroglu, 2007). The

study by Suarez-Arrones *et al*. (2013) investigated rugby union referees. The results from this study show that on average, a total distance of 6 322.2m was covered in a match with their average heart rate being in zone four, between 81 and 90% of the maximum heart rate. A study conducted by Emmonds *et al*. (2015) revealed that in the last 15 minutes of the game the lowest accuracy from referees was observed, suggesting that physical and mental fatigue occurs in the final stages of the match or could also be as a result of a team's tactical modifications. Fatigue alters the required intensity needed for a referee to get into position (Krustrup & Bangsbo, 2001; Krustrup *et al*., 2009), potentially resulting in inaccurate decision-making.

More experienced referees have a better ability to read play and to predict their positioning during a game (Castagna *et al*., 2004). The positioning and experience of the referee plays a major role for interpreting the game and applying the correct law, placing great demands on the fitness of the referee to get into the correct position (Cochrane *et al*., 2003; Mascarenhas *et al*., 2004; Mallo *et al*., 2012). There is no "best" position that a referee needs to adopt in every situation, but there are some important points for referees to consider in order to be in the best possible position: (1) have clear vision of as many players as possible; (2) have clear vision of the ball and ball carrier to determine possible knock-ons and forward passes; (3) be close to play to make immediate and accurate decisions; (4) interact with players to ensure continuity and to manage preventative measures; and (5) be in a position that does not obstruct the players (World Rugby, 2016b). Two key areas are addressed for the positioning of referees. The first area is ball in hand (general movement). A good position when the ball is in the hands of a player is in ball-line running. Figure 2.3 and 2.4 show the two different positions for ball line running (World Rugby, 2016b). The second area is when the ball is on the ground (the breakdown). There are four different possible positions for a referee approaching the breakdown, namely: (1) Defence (Right); (2) Defence (Left); (3) Attack (Right); and (4) Attack (Left). The term *"ball-inside-outside"* describes the referee's action at the breakdown.

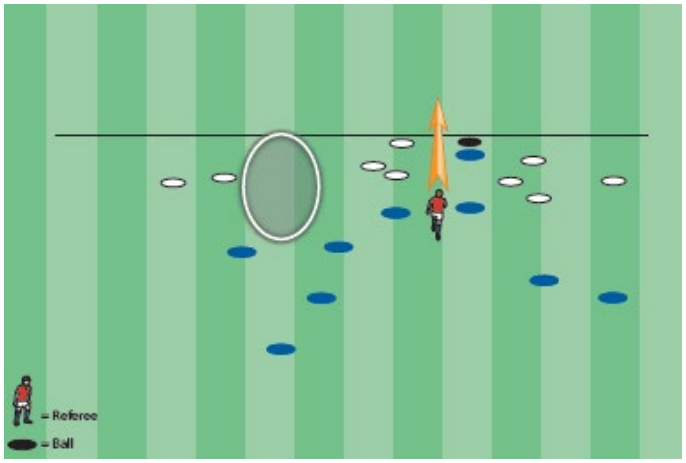

FIGURE 2.3: **BALL LINE RUNNING - BALL PASSED LATERALLY**

FIGURE 2.4: **BALL LINE RUNNING - BALL IS CARRIED FORWARDS**

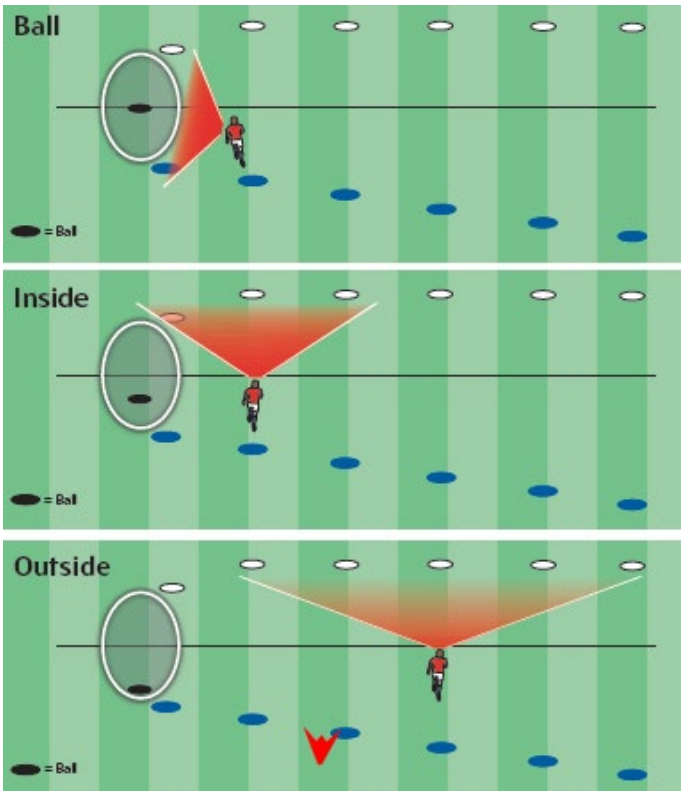

FIGURE 2.5: **REFEREE BODY POSITION DURING THE BREAKDOWN. "BALL-INSIDE-OUTSIDE"** (World Rugby, 2016b)

Figure 2.5 illustrates the *"ball-inside-outside"* position that a referee adopts at the breakdown. When referees arrive at the breakdown, they first detect the ball and will stand on the same side as the ball. Once the ball is detected, a referee must ensure clear vision of all the players involved and follow a ball line-running pattern that faces the tackle sideways. After locating the ball the referee will look at the "inside defence" where once the contest is won adopt a new body position where the referee will face the defenders goal line and will exit the contact event through an east to west pattern allowing space near the tackle or ruck. Last position is "outside defence" at the breakdown where the referee is facing the defending team and will exit as the ball leaves the ruck.

BEHAVIOUR TOWARDS INJURY PREVENTION

Player behaviour

Player behaviour and attitude towards injury prevention and safety is regarded as a risk factor for injury in rugby (Gianotti *et al*., 2009; Hendricks *et al*., 2012; Hendricks *et al*., 2015). Intrinsic risk

factors for injury in players include: age; body composition; knowledge of specific techniques; implementation of techniques; physical and mental capacities; previous injury; attitude; and genetics (Van Mechelen *et al.*, 1992; Meeuwisse, 1994; Gissane *et al*., 2001; Bahr & Krosshaug, 2005; McIntosh, 2005). Extrinsic risk factors for injury in players include: coaching; training; behaviour; equipment; and environment (Van Mechelen *et al.*, 1992; Meeuwisse, 1994; Gissane *et al.*, 2001; Bahr & Krosshaug, 2005; McIntosh, 2005). When players accept and adopt behaviours towards safety it results in a successful injury prevention strategy, which is achieved through increasing player awareness and promoting these attitudes (Lund & Aarø, 2004; Gianotti *et al*., 2009).

Player behaviours include: training habits; on-field actions; use of equipment; and interaction with coaches, opponents, referees and teammates. Other determinants of behaviour include: social influences; self-efficacy (the ability to perform a specific skill); and attitude (Van Mechelen *et al.*, 1992; Lund & Aaro, 2004; Bahr & Krosshaug, 2005; McIntosh *et al*., 2005; Van Tiggelen *et al.*, 2008). Psychological internal risk factors affecting player behaviour include: competitiveness; motivation; and perception of risk, which all predispose a player to injury (Meeuwisse, 1994; Lee *et al*., 2001; Bahr & Krosshaug, 2005). Behaviour can be affected by attitudes, social factors, and perceptions of self-efficacy resulting in positive or negative behaviours (Kok & Bouter, 1990; Greenlees *et al*., 1999). Multiple behaviours can increase injury risk factors and mechanisms (Verhagen *et al*., 2010 - see Figure 2.6). The players, coaches and referees' behaviours have a relationship with risk factors and injury mechanisms, which will either be positive or negative, if negative these behaviours will result in an injury. In this model, psychological and behavioural factors are considered risk factors, or potential injury mechanisms that result in a sport injury (Verhagen *et al*., 2010).

FIGURE 2.6*:* **THE RELATIONSHIP BETWEEN BEHAVIOUR, INJURY RISK FACTORS, INJURY MECHANISMS AND SPORTS INJURY** (Verhagen *et al*., 2010)

Coaches behaviour

Coaches behaviour has an impact on players and injury risks because they aim to improve skill levels and performance (Reid *et al*., 2007; Cushion *et al*., 2012). The main responsibility of a coach is to prepare players for the technical and physical requirements of a specific sport (Van Tiggelen *et al*., 2008*)*. Educating coaches is an important component of sport injury prevention and risk management models (Chalmers *et al*., 2004; Carter & Muller, 2008; Posthumus & Viljoen, 2008; Twomey *et al*., 2009; Hendricks & Sarembock, 2013; White *et al*., 2014). Most coaches have a preferred coaching style because of their experience in the sport (Harvey *et al*., 2010), however, this style might not be individualised to the needs of all players (Cushion *et al*., 2012). Traditional coaching approaches are effective with short-term knowledge retention, whereas a problem-based approach is more effective for long-term knowledge retention (Gilbert *et al*., 2009). Limited research that has been conducted on coach behaviour in rugby (Carter & Muller, 2008; Hendricks *et al*., 2012). Coaches need to enforce the laws, coach, and teach correct contact techniques during practises for players to execute them correctly in matches. Coaches and the environments they

create can have an impact on players sporting experience because of the behaviours, values and priorities of the coach (Smoll & Smith, 2001).

SUMMARY

Rugby has a high incidence rate because of the high number of injuries occurring in contact events, and therefore, has led to the development of injury prevention programmes with a focus on safety, education of referees, players and coaches, as well as the execution of safe techniques during play. Incorrect safety techniques are a major risk factor for injuries and need to be identified and corrected. The risk factors for school level rugby are unknown because limited research were conducted at this level, with the majority of research focusing on investigating professional players. The majority of research has mainly focused on tackle events, because it occurs the most and brings about the majority of injuries. Limited research was conducted on the ruck cleanouts, despite causing the second highest number of injuries. Factors playing a role in injuries at ruck cleanouts can be associated with player behaviour and referee decision-making skills and neither have been investigated in detail. By having a more detailed understanding of player behaviour and referee decision-making at the ruck cleanout, could help inform and develop injury prevention programmes.

Surveillance is the first step in injury prevention. By surveying an incident and sanctioning rate of legal and illegal (both illegal not dangerous and illegal dangerous) ruck cleanouts will assist with the development of new and the adaption of current injury prevention programmes. Surveillance and injury management could be achieved through video analysis where performance, injury outcomes, identification of incorrect techniques, identification of risk factors and behaviour of the referee and players through their decision-making on the field could be analysed. Players have a critical role in changing their behaviour on the field by using safe and correct techniques and abiding to the laws of the game. At the same time, the referee has a critical role in preventing of injuries through accurate decision-making and by adhering to the laws of the game in order to make the game as safe as possible for the players. Without player or referee input, an injury prevention programme will be ineffective, and players will still be at risk of injury.

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CHAPTER THREE

METHODOLOGY

Chapter three is included herewith in accordance with the referencing guidelines of the Department of Sport Science, Stellenbosch University.

INTRODUCTION

Rugby union ("rugby") is a high impact contact sport with a high injury rate (Tommasone & Valovich McLeod, 2006; Brooks & Kemp, 2008; Williams *et al*., 2013). The majority of the injuries in schoolboy rugby matches occur during contact events, with tackles resulting in the

greatest number of injuries (39.6 to 64%), whereas rucks result in the second greatest number of injuries (8.3 to 31.5%) (Bleakley *et al*., 2011; Freitag *et al*., 2015). Published research has focused on the tackle event (Fuller *et al*., 2008; Burger *et al*., 2014; Mathewson & Grobbelaar, 2015; Brown *et al*., 2018; Davidow *et al*., 2018; Hendricks *et al*., 2018; Tierney & Simms, 2018; Tierney *et al*., 2018), but limited research has been conducted on rucks and specifically the cleanout. Therefore, the current study investigated the ruck cleanout over a five-year period during the Under 18 Craven Week rugby union tournaments. Specifically, the aim was to investigate player and referee behaviour pertaining to legal and illegal not dangerous and illegal dangerous ruck cleanouts during the rugby tournament to raise awareness regarding the number of illegal not dangerous and illegal dangerous ruck cleanouts that are not sanctioned by referees, as well as player behaviours that potentially leads to injury. This chapter describes the step-by-step process of the research project, including: the research design; approach to the problem; data collection procedures; ethical aspects; and interpretation of the findings.

RESEARCH DESIGN

The research design of the current study followed a descriptive approach where situations were examined on an observational basis and retrospective televised video footage were used to analyse a specific situation (i.e., ruck events) (Williams, 2007). Descriptive research describes a phenomenon and its characteristics and provides more information on what happened than how or why (Nassaji, 2015). Observation and survey tools are often used to gather data in descriptive research (Gall *et al*., 2007). Observation tools were used to gather data in the current study. The data was analysed quantitatively using frequencies (number of observations) and percentages and reported as frequencies and percentages. Ethical approval was obtained and from the Research Ethics Committee: Human Research, Stellenbosch University (REC-2019-10416).

APPROACH TO THE PROBLEM

The current study is descriptive in nature and used retrospective video-based performance analyses to investigate ruck cleanouts during the Under 18 Craven Week rugby tournaments between 2015 and 2019. The televised video footage were analysed using Nacsport software (version: Scout Plus, Spain: 2008). The Nacsport video software allowed a specific event to be coded and then reflected as performance indicators (PI's). The PI's for this study were decided through an identification

and selection process discussed in detail in the coding subsection below. During the coding, the coder (primary investigator) was at liberty to pause, rewind and watch the footage in slow motion. Each ruck cleanout was coded according to the PI's and operational definitions identified and compiled by the expert panel (more details below).

SAMPLE

All matches (N=118) played during the South African Under 18 Craven Week Tournament between 2015 and 2019 were analysed. The video recordings were obtained from the South African Rugby Union. The South African Craven Week Rugby tournament is the biggest schoolboy rugby competition for the most elite players and is for developmental referees and it is televised.

Inclusion criteria

All the ruck cleanouts that took place during the Under 18 Craven Week rugby tournament during 2015 and 2019 were included.

Exclusion criteria

Vague footage (angle is too far, blurry, or unable to see due to players blocking the view) were not allowed.

DATA COLLECTION PROCEDURE

Identification of performance indicators

The performance indicators (PI's) and operational definitions for the purpose of the current study were validated before the start of the study. The PI's and operational definitions were validated by the methods prescribed by O'Donoghue (2010) and Watson *et al*. (2017). According to Morrow *et al*. (2005) and Thomas and Nelson (1996), there are two types of validity: (1) norm referenced validity; and (2) domain referenced validity. The current study used norm referenced validity. Norm referenced validity measures variables and compares player performance to norms against specific populations. There are four categories under norm referenced validity: (1) logical validity (a variable that is valid by definition); (2) content validity (the extent to which the variable covers different components of the topic of interest); (3) criterion validity (variable is validated against a gold standard that has been accepted); and (4) construct validity (validity of a specific construct

used to represent a property that is not directly observable) (O'Donoghue, 2010). The current study focused on one norm referenced validity, namely criterion validity (O'Donoghue, 2010). Another method to measure validity is through a quantitative method called multiple regression. Multiple regression techniques are used to identify each PI's relative contribution in predicting the outcome (Choi *et al*., 2006).

The initial PI's and operational definitions were based on published peer-reviewed studies in this field of study (Van Rooyen *et al*., 2010; Kraak & Welman, 2014; Hendricks *et al*., 2018; Kraak *et al*., 2019; Hendricks *et al*., 2020), as well as consulting an expert panel (N=7). The panel consisted of: (1) a rugby injury prevention specialist; (2) a rugby coach (focusing on the ruck area); (3) a rugby player; (4) a rugby referee; (5) a rugby referee coach; and (6) two South African BokSmart™ representatives. The expert panel also decided whether the PI's were appropriate and that their operational definitions were clear. The agreed upon PI's and operational definitions that were discussed with the panel are presented in Table 3.1. Clearly defined PI's have the potential to be of great benefit because they are valued by coaches, stakeholders, such as BokSmart™ and referees who use PI's to provide feedback on important aspects of gameplay (Hughes *et al*., 2012; Bremner *et al*., 2013) and to inform tactical approaches to the game (Bishop & Barnes, 2013). Clearly defined PI's will help predict future performance (Boucher, 2017) and could also potentially assist in preventing future injuries. Reviewing footage using PI's to code certain characteristics during the match will help to better understand player and referee behaviours at ruck cleanouts. This, in turn, will provide knowledge that can be used to develop specific injury prevention strategies going forward.

TABLE 3.1: PERFORMANCE INDICATORS AND OPERATIONAL DEFINITIONS USED IN THE STUDY

Performance indicator	Operational definitions
Ruck. (World Rugby, 2020)	The ruck is defined as a phase of play where one or more players from each team, who are on their feet and in physical contact close around the ball, which is on the ground.
Ruck cleanout. (Kraak *et al*., 2019)	A cleanout during a ruck is when the players contesting in the ruck make contact, drive with the legs and clear the opposition off or away from the ball in an attempt to either turnover or maintain possession.
Ruck cleanout outcome. (World Rugby, 2020)	Legal: according to the 2020 WR law book. Illegal: according to the 2020 WR law book.
Illegal ruck cleanout outcomes. (Kraak *et al*., 2019)	Dangerous clean out: action was deemed dangerous if the action of the player could lead to possible injury of (a) himself, (b) own players, and (c) opposition players.
Score outcome	Based on points difference between winning and losing teams: Based on whether the attacking team was winning, losing or drawing at the time of the ruck event, based on the score.
Match-time period. (Brown *et al*., 2018)	Quarter 1: 0 to 17.5 minutes; Quarter 2:17.5 to 35> minutes; Quarter 3: 35 to 52.5 minutes; and Quarter 4: 52.5 to 70> minutes.
Zonal locations. (Van Rooyen *et al*., 2010)	Zone A: Attacking area between 22m area and the try line. Zone B: Attacking area between 22m area and halfway line. Zone C: Defence area between 22m area and the halfway line. Zone D: Defence area between 22m area and the try line.
Channels. (Den Hollander *et al*., 2016; Hendricks *et al*., 2018)	Channel 1: From left touchline to 15m lines. Channel 2: In between the 15m. Channel 3: 15m to right touchline line.
Attacking team. (Kraak & Welman, 2014)	The team in possession of the ball.
Defence team (Kraak & Welman, 2014)	The team not in possession of the ball.
Number of players involved in the cleanout: Attack/Defence. (Hendricks *et al*., 2018)	Number of attacking players that are actively involved in the ruck contest and cleanout: Ball carrier (Player 1 [Attacking team]) - player carrying the ball; Tackler (Player 2 [Defending team]) - tackler; Cleaner 1 (Player 3 [Attack or defending team]) - first cleaner; Cleaner 2 (Player 4 [Attack or defending team]) - second cleaner; Cleaner 3 > (Player 5> [Attack or defending team]) - third or more cleaners.
Types of illegal and dangerous ruck cleanouts. (World Rugby, 2020)	*Neck roll*: A cleaner must not grasp an opposition player around the neck area to clean out. *Not supporting own body weight*: A player cleaning out a ruck must be on his feet. *Joining the ruck while in an offside position*: A player cleaning at the ruck may not do so while in an offside position. Non-participants at the breakdown must be behind the hindmost foot of the last player in their side of the ruck. *Shoulder charge*: A player must not charge into a ruck. Charging includes any contact made without use of the arms, or without grasping a player. *Side entry*: A cleaner must join alongside, but not in front of, the hindmost player. *Not grasping on teammate when cleaning*: A player joining a ruck must bind onto a teammate or an opponent, using the whole arm. The bind must either precede, or be simultaneous with, contact with any other part of the body of the player joining the ruck. *Cleaning a player not involved in the ruck*: A cleaner must not take-out opposition players who are not part of the ruck. *Contact above shoulder of opposition player*: A cleaner must not make contact with an opponent above the line of the shoulders.

Cleaner technique at the ruck (Attacking team). (Hendricks *et al*., 2018)	*Clearing*: Attackers are actively driving opponents off the ball. *Protecting the ball*: Attackers are positioned over the ball to prevent opponents' access. *Clearing and protecting*: Attackers actively clear the ruck first, before protecting the ball. *Protecting and clearing*: Attackers actively protects the ball first, before clearing the ruck.
Cleaner technique at the ruck (Defending team). (Hendricks *et al*., 2018)	*Early counter ruck*: Defenders compete for the ball without the use of their hands before attackers had secured possession. *Jackal*: A defender competes for the ball using his hands after a tackle was made but before a ruck is formed. *No pressure*: Defenders are not actively attempting to regain possession. *Late counter ruck*: Defenders compete for the ball without the use of their hands after attackers had secured possession of the ball.
Arrival time of referee (within 1m of the ruck)	Early: Before the ruck has commenced Late: After the ruck has commenced Not in frame: the referee could not be seen due to the camera focusing in on the ruck cleanout
Positioning of referee (static)	Behind ruck close: within 1m Behind ruck far:1.1m or further away 45º at ruck close: within 1m 45 º at ruck far: 1.1m or further away Not in frame: the referee could not be seen due to the camera focusing in on the ruck cleanout
Line of positioning (dynamic)	Attacking line: standing on the attack side Defensive: standing on the defence side Not in frame: the referee could not be seen due to the camera focusing in on the ruck cleanout
Influence of sanctioning illegal ruck cleanouts by referees	*Players obstructing referee view (poor arrival position)*: Poor arrival position means referee cannot maintain ball vision 100% of the time *Focus on offside line*: not managing the breakdown whilst the contest is still occurring – in other words the ball has not been won and the referee is looking at the offside line *No obstruction*: referee is in a position where neither players nor their position is blocking the event *Position obstructing*: referee is in a position where they cannot see clearly *Not in frame:* the referee could not be seen due to the camera focusing in on the ruck cleanout
Correctly sanctioned (World Rugby, 2020)	Yes: according to the WR Law Book No: according to the WR Law Book

Selection of performance indicators

To ensure logical and content validity for describing player and referee behaviours and actions, the list will be more inclusive than exclusive (Hendricks *et al*., 2018). After phase 1, the expert panel was consulted to review the validity and relevance of the proposed PI's, and the lucidity of the operational definitions. The expert panel agreed that the PI's and operational definitions for the study were appropriate and clear and no further changes were required.

Reliability

The reliability of the coded ruck cleanouts was tested using intra and inter-rater reliability and was tested before and after the coding. Before the initial coding, the primary researcher coded a full

match before commencement of the data collection and recoded the same match 7 days later (intra). An external coder and an international referee also coded the same match and recoded the match 7 days later (inter). After the initial coding, the primary researcher and an external coder re-coded 25% (N=30) of the matches that were randomly selected by the statistician for the intra and inter-rater reliability. The reliability of the intra and inter-rater reliability for before and after coding was determined by the Intraclass Correlation Coefficient (ICC) of the test and retest data. Intra and inter-rater agreement was interpreted as follows: poor (< 0.20), fair (0.30 to 0.40), moderate (0.50 to 0.60), strong (0.70 to 0.95) and almost perfect (> 0.95) (Gratton & Jones, 2004). The results for the intra-coder reliability for the different stages of the research was as follows: before commencement of coding r=0.97 (almost perfect) and after coding 0.95 (almost perfect). The total inter-coder reliability for the external coder before commencement of coding r=0.96 (almost perfect) and after coding r=0.94 (strong). The total inter-coder reliability for the international referee after the coding was r=0.94 (strong).

Statistical analysis

Prof Martin Kidd of the Centre for Statistical Consultation, Stellenbosch University, conducted the statistical analysis. The Statistica (version 13.3.721.1 Data Processing package was used to process the data.

Research article One

Descriptive data of the PI's was reported as frequencies (number of observations) and percentages, with an applied significance level of 5% ($p<0.05$). Differences between categorical frequencies were determined by using Chi-Square. Some indicators are expressed as percentages, which according to Hughes and Bartlett (2002) provides a more accurate analysis of team performance. Four a priori proportions were decided upon as proxies of player behaviour, similar to that used by Brown *et al*. (2018) and Kraak *et al*. (2019). Player behaviour was measured by: (a) *legal* ruck cleanouts as a percentage of *all* ruck cleanouts (i.e., legal, illegal not dangerous and illegal dangerous combined); (b) *illegal* ruck cleanouts as a percentage of *all* ruck cleanouts; (c) *illegal not dangerous* ruck cleanouts as a percentage of illegal ruck cleanouts (i.e., illegal not dangerous and illegal dangerous combined); and (d) *illegal dangerous* ruck cleanouts as a percentage of *all* illegal ruck cleanouts. A Classification and Regression Tree (CART) model was completed with the independent variables being the PI's listed in Table 4.1.

Research article Two

Descriptive data of the PI's was reported as frequencies (number of observations) and percentages, with an applied significance level of 5% ($p<0.05$). Differences between categorical frequencies were determined by using Chi-Square. Some indicators are expressed as percentages, which according to Hughes and Bartlett (2002) provides a more accurate analysis of team performance. Six *priori* proportions were decided upon as proxies for measuring referee behaviour, similar to that used by Brown *et al*. (2018) and Kraak *et al*. (2019). Referee behaviour was measured by (a) *sanctioned illegal* ruck cleanouts as a percentage of *all illegal* ruck cleanouts; (b) *not-sanctioned illegal* ruck cleanouts as a percentage of *all illegal* ruck cleanouts; (c) *sanctioned illegal not dangerous* ruck cleanouts as a percentage of *all illegal* ruck cleanouts; (d) *not sanctioned illegal not dangerous* ruck cleanouts as a percentage of *all illegal* ruck cleanouts (illegal not dangerous and illegal dangerous combined); (e) *sanctioned illegal dangerous* ruck cleanouts as a percentage of *all illegal* ruck cleanouts and (f) *not sanctioned illegal dangerous* ruck cleanouts as a percentage of *all illegal* ruck cleanouts.

ETHICAL CONSIDERATIONS

The protocol of this study was submitted to the Departmental Ethics Screening Committee (DESC) at the Department of Sport Science and the Research Ethics Committee of Stellenbosch University (REC). The study was considered low risk because of the televised video footage being available in the public domain (REC-2019-10416). Data was stored on a password protected computer, external hard drive and on a protected file within the programs used to store the data. The primary researcher and two supervisors had access to the data. The statistician (Prof Martin Kidd - Centre for Statistical Consultation, Stellenbosch University), who assisted with the data analysis, worked with the anonymous coding system. The data will be kept for five years where after it will be shredded and destroyed. The goal will be to publish two articles in which group data will be discussed and compared with the existing standards in the limited literature. Only group data will be reported, and therefore, no player or team can be identified. Both the supervisors and participants were aware that intellectual property, including data generated during postgraduate research and study, belongs to Stellenbosch University according to the SU IP policy. Copies of all data (raw and analysed) was submitted to the supervisor on completion of the study.

INTERPRETATION OF FINDINGS

The findings will be published in two research articles. Research article One will focus on the analysis of ruck cleanouts to investigate player behaviour will be prepared according to the guidelines of the Journal of Sports Sciences. Research article Two will focus on the non-sanctioning of illegal ruck cleanouts by on-field referees looking specifically at referee behaviour and decision-making and will be prepared according to the guidelines of the Journal of Science and Medicine in Sport. The findings can assist in refining current injury prevention programmes. The application of this study will: 1) assist BokSmart™ with informative data and content for their injury prevention workshops; 2) provide the South African Rugby Union coaching education department with information to enhance their coach education, coaching manuals, and interventions; and 3) the South African Rugby Union referee department can use the information for referee education and coaching and ultimately improve referees' decision-making and safety standards at the ruck.

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CHAPTER FOUR

RESEARCH ARTICLE ONE

AN INVESTIGATION INTO LEGAL AND ILLEGAL RUCK CLEANOUTS DURING ELITE YOUTH RUGBY TOURNAMENTS

Chapter Four is included herewith in accordance with the author guidelines provided for the esteemed Journal of Sports Sciences (Appendix B). However, to provide an orderly and well-drafted product for this thesis, the article has been edited to represent an actual published article as it would appear in the journal. However, this does not imply that the article has been accepted or will be accepted for publication. Consequently, the referencing style used in this chapter may differ from styles used in other chapters of the thesis.

Title page

Title: An investigation into legal and illegal ruck cleanouts during elite youth rugby tournaments

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An investigation into legal and illegal ruck cleanouts during elite youth rugby tournaments

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Abstract

The ruck and the tackle are the most frequently occurring events in rugby union. It is important to investigate ruck cleanouts because it is responsible for the second highest number of injuries, which need to be reduced in order to promote player safety. The aim of the current study was to investigate and compare incidents of legal and illegal ruck cleanouts during the Craven Week tournaments between 2015 and 2019. A total of 118 games were analysed using Nacsport Scout Plus software. In total, 35 545 ruck cleanouts were coded, of which 32 641 (91.8%) were legal and 2 904 (8.2%) were illegal. Of the 2 904 illegal cleanouts, 2 676 (7.5%) were deemed not dangerous and 228 (0.6%) were considered dangerous. The most common non-dangerous and dangerous ruck cleanouts were "*not supporting own body weight*" (2 498; 99.4%, p=0.01) and "n*eck roll*" (147; 100.0%, p=0.02), respectively. Player behaviour needs to be addressed, emphasised, and improved through correct and effective technique drills during training, changing player behaviour and improving decision-making. The risk of injury during the ruck can be reduced through the implementation of safe and effective techniques by coaches during training.

Keywords: Rugby union, player behaviour, injury prevention, performance analysis

4.1. Introduction

Rugby union (hereafter referred to as rugby) is a collision sport with contact events forming a major part of the game (Williams *et al*., 2013), which results in a higher injury risk when compared to other team sports (Holtzhausen *et al.*, 2006; Williams *et al*., 2013; Burger *et al*., 2016). For instance, during the 2019 Currie Cup Tournament (Starling *et al*., 2019), at a senior level, time-loss match injuries occurred at a higher rate of 94 injuries per 1 000 player exposure hours

compared to the 2018 South African Rugby Union (SARU) Youth Week Tournaments. At the under 18 Craven Week and the under 18 Academy Week, 16 injuries per 1 000 player exposure hours and 22 injuries per 1 000 player exposure hours were reported, respectively (Starling *et al*., 2019). Tackle and ruck events are the most common phases of play, with the ruck occurring ~116 times during an 80-minute match (Hendricks *et al*., 2014), which results in the second highest number of injuries (6.0 to 17.0%) at a professional level (Fuller *et al*., 2007; Posthumus & Viljoen, 2008; Hendricks & Lambert, 2010; Roberts *et al*., 2015). This differs from school level rugby, where rucks are responsible for 16% of injuries (Palmer-Green *et al*., 2013). Since the advent of professionalism in rugby in 1995, the number of rucks per game have increased. For instance, when comparing the Rugby World Cups of 1995 and 2015, there was a mean of 94 and 178 rucks per game, respectively (World Rugby, 2015). The increased frequency of exposure to rucks and associated injury risk raises serious concerns regarding player safety.

The ruck is a phase of play that usually follows a tackle, where two additional players, one from each team, are on their feet and are in physical contact on, around, or over the ball (World Rugby, 2019). A cleanout during a ruck, is when the players contesting in the ruck, make contact, drive with the legs, and clear the opposition off or away from the ball in an attempt to either turnover or maintain possession. To date, only one study has investigated ruck cleanouts in rugby (Kraak *et al*., 2019). Specifically, this study identified and analysed a total of 22 281 ruck cleanouts during the 2018 Super Rugby competition. Of the 22 281 ruck cleanouts, 2 111 (9.0%) were deemed illegal according to the World Rugby (WR) laws of the game, with an average of 18 ruck cleanouts occurring per match. Out of the 2 111 illegal ruck cleanouts, 1 087 (51.0%) were dangerous, at an average of 10 per match (Kraak *et al*., 2019). The ruck, by being physically, mentally, emotionally, or a combination extremely exhaustive, can impair players' decision-making abilities (Deutsch *et al*., 2007; Lorains *et al*., 2013; Wheeler *et al*., 2013), and can result in poor techniques being used (Hendricks *et al*., 2012). This can subsequently increase injury risk, because players become more vulnerable to making errors in a fatigued state (Deutsch *et al*., 2007; Lorains *et al*., 2013).

The aforementioned injury risks need to be investigated and the first step in injury prevention is surveillance (Van Mechelen *et al*., 1992). Injury surveillance research published on the ruck is limited (Best *et al*., 2005; Freitag *et al*., 2015; Kraak *et al*., 2019; Mitchell & Tierney, 2020), especially at a school level. Having surveillance data on illegal and dangerous ruck

cleanouts from player, coach, and referee perspectives could help governing bodies (e.g., South African Rugby Union [SARU], World Rugby [WR]) to improve their current injury prevention programmes by applying research findings and creating behaviour change among players, coaches, and referees (Viljoen & Patricios, 2012; Carter, 2015; Archbold *et al*., 2017). To create such behaviour change, individuals need to use the information obtained from injury prevention research and translate it into their applied practice (Viljoen & Patricios, 2012). Video analysis which has become an integral part of injury surveillance studies, is also a tool, which by understanding the mechanism better, could potentially help reduce the number of injuries. It can also be used for assessing proficiency in rugby contact techniques and player decision-making, based on objective data and specific technical criteria. This can help to identify, diagnose, and correct technical and tactical problem areas (O'Donoghue, 2006; Laird & Waters, 2008; Wright *et al*., 2012; Sarmento *et al*., 2015). Player's attitudes and behaviours have been linked to injury, and therefore, could be regarded as risk factors (Finch *et al*., 2002; Emery *et al*., 2009; Gianotti *et al*., 2009; Whatman *et al*., 2018). Coaches need to monitor these risk factors and ensure that their players are technically and tactically prepared by teaching safe techniques and contact skills during practise. In addition, coaches have a responsibility to teach players to play and adhere to the laws of the game (Kraak *et al*., 2016, 2017). With a focus on injury prevention, very little research has been conducted on player behaviour in ruck cleanouts, because the majority of research has focused on tackles (Finch *et al*., 2002; Hendricks *et al*., 2012).

The primary aim of this study was therefore to investigate technical execution and player behaviour during ruck cleanouts. By comparing the incidence and player behaviour during the ruck cleanout outcomes across chronological years, match time periods, match outcome, zonal pitch locations, channel locations, and type of illegal cleanouts, this study further aimed to measure the frequency and type of both legal and illegal ruck cleanouts, during the Under 18 Craven Week rugby tournaments between 2015 and 2019. Illegal ruck cleanouts were further subdivided into '*not dangerous*' and '*dangerous*' illegal cleanouts for additional analysis. It is important to investigate ruck cleanouts, because this phase of play is responsible for the second highest number of injuries, and the findings can be used to promote improved player safety.

4.2. Methodology

Sample

In the current study, video recordings (N=118 matches) during the South African Rugby Union (SARU) Under 18 Craven Week tournaments between 2015 and 2019 were analysed. All of the video recordings were supplied by the SARU's technical department. Video recordings and ruck cleanouts were excluded if the footage was too vague, the angle was poor or the ruck cleanout was located too far from the camera, the image was blurry, or the coder was unable to see the event because of players obstructing the view. Ethical approval was obtained from the Research Ethics Committee: Human Research, Stellenbosch University (REC-2019-10416).

Data collection procedure

Coding

The video recordings were analysed using Nacsport software (Version: Scout Plus, Spain: 2008). The software allows for a specific event to be coded and then to be reflected as performance indicators (PI's). During the coding, the coder (primary researcher) was at liberty to pause, rewind, and watch the footage in slow motion. Each ruck cleanout was coded according to the PI's and operational definitions identified (see Table 4.1). The initial PI's and operational definitions were developed based on published peer-reviewed studies in this field (Van Rooyen *et al*., 2010; Kraak & Welman, 2014; Hendricks *et al*., 2018; Kraak *et al*., 2019), and by consulting an expert panel (N=7). This expert panel consisted of: (1) a rugby injury prevention specialist; (2) a rugby coach (specialising in the ruck area); (3) a rugby player; (4) an international rugby referee; (5) a rugby referee coach; and (6) two South African BokSmart^{TM} representatives. After deciding on the PI's, the expert panel was consulted to review the validity and relevance of the proposed PI's and the lucidity of the operational definitions. The expert panel agreed that the PI's and operational definitions for the study were appropriate and clear, no further changes were made. Prior to coding, a "gold standard" was set by an international referee, using the definitions from the 2019 WR Laws of the Game and by analysing a match in conjunction with the primary coder. This process has also been employed in previous research (e.g., Brown *et al*., 2018; Kraak *et al*., 2019).

Table 4.1. The performance indicators and operational definitions used in the study.

Performance indicators	Operational definitions
Ruck. (World Rugby, 2020)	The ruck is defined as a phase of play where one or more players from each team, who are on their feet and in physical contact close around the ball, which is on the ground.
Ruck cleanout. (Kraak *et al*., 2019)	A cleanout during a ruck is when the players contesting in the ruck make contact, drive with the legs, and clear the opposition off or away from the ball in an attempt to either turnover or maintain possession.
Ruck cleanout outcome. (World Rugby, 2020)	Legal: according to the 2020 WR law book. Illegal: according to the 2020 WR law book.
Illegal ruck cleanout outcomes. (Kraak *et al*., 2019)	Dangerous cleanout: action was deemed dangerous if the action of the player could lead to possible injury of (a) himself, (b) own players, and (c) opposition players.
Score outcome	Based on points difference between winning and losing teams: Based on whether the attacking team was winning, losing, or drawing at the time of the ruck event, based on the score.
Match-time period. (Brown *et al*., 2018)	Quarter 1: 0 to 17.5 minutes Quarter 2: 17.5 to 35 minutes Quarter 3: 35 to 52.5 minutes Quarter 4: 52.5 to 70 minutes
Zonal locations. (Van Rooyen *et al*., 2010)	Zone A: Attacking area between 22m area and the try line. Zone B: Attacking area between 22m area and halfway line. Zone C: Defence area between 22m area and the halfway line. Zone D: Defence area between 22m area and the try line.
Channels. (Den Hollander *et al*., 2016; Hendricks *et al*., 2018)	Channel 1: From left touchline to 15m lines. Channel 2: In between the 15m. Channel 3: 15m to right touchline line.
Attacking team. (Kraak & Welman, 2014)	The team in possession of the ball.
Defending team. (Kraak & Welman, 2014)	The team not in possession of the ball.
Number of players involved in the cleanout: Attack/Defence. (Hendricks *et al*., 2018)	Number of attacking/defending players that are actively involved in the ruck contest and cleanout: Ball carrier (Player 1 (Attack): player carrying the ball Tackler (Player 2 (Defence): tackler Cleaner 1 (Player 3 (Attack or defence): first cleaner Cleaner 2 (Player 4 (Attack or defence)): second cleaner Cleaner ≥3 (Player ≥5) (Attack or defence)): third or more cleaners.
Types of illegal and dangerous ruck cleanouts. (World Rugby, 2020)	*Neck roll*: A cleaner must not grasp an opposition player around the neck area to clean out. *Not supporting own body weight*: A player cleaning out a ruck must be on his feet. *Joining the ruck while in an offside position*: A player cleaning at the ruck may not do so while in an offside position. Non-participants at the breakdown must be behind the hindmost foot of the last player in their side of the ruck. *Shoulder charge*: A player must not charge into a ruck. Charging includes any contact made without use of the arms, or without grasping a player. *Side entry*: A cleaner must join alongside, but not in front of, the hindmost player. *Not grasping on teammate when cleaning*: A player joining a ruck must bind onto a teammate or an opponent, using the whole arm. The bind must either precede, or be simultaneous with, contact with any other part of the body of the player joining the ruck. *Cleaning a player not involved in the ruck*: A cleaner must not take-out opposition players who are not part of the ruck. *Contact above shoulder of opposition player*: A cleaner must not make contact with an opponent above the line of the shoulders.
Cleaner technique at the ruck (Attacking team). (Hendricks *et al*., 2018)	*Clearing*: Attackers are actively driving opponents off the ball. *Protecting the ball*: Attackers are positioned over the ball to prevent opponents' access.

	Clearing and protecting: Attackers actively clear the ruck first, before protecting the ball. *Protecting and clearing*: Attackers actively protects the ball first, before clearing the ruck.
Cleaner technique at the ruck (Defending team). (Hendricks *et al*., 2018)	*Early counter ruck*: Defenders compete for the ball without the use of their hands before attackers had secured possession. *Jackal*: A defender competes for the ball using his hands after a tackle was made but before a ruck is formed. *No pressure*: Defenders are not actively attempting to regain possession. *Late counter ruck*: Defenders compete for the ball without the use of their hands after attackers had secured possession of the ball.

Reliability

The reliability of the coded ruck cleanouts was tested using intra and inter-rater reliability and was tested before and after the coding (Gratton & Jones, 2004). Before the commencement of data collection, the primary researcher coded a full match and re-coded the same match 7 days later (intra-rater reliability). An external coder and international referee also coded the same match and recoded the match 7 days later (inter-rater reliability). After the initial coding, the primary researcher, and an external coder re-coded 20 of the matches that were randomly selected by the statistician for the intra- and inter-rater reliability. The Intraclass Correlation Coefficient (ICC) was used to determine the intra and inter-rater reliability of the test and retest data. Intra- and inter-rater agreement was interpreted as follows: poor (<0.20), fair (0.30-0.40), moderate (0.50-0.60), strong (0.70-0.95), and almost perfect (>0.95) (Gratton & Jones, 2004). Intra-rater reliability was almost perfect both before (r=0.97) and after (r=0.95) coding. Inter-coder reliability for the external coder was strong almost perfect (r=0.96) before commencement of coding and strong (r=0.94) after coding. The total inter-coder reliability for the international referee after the coding was r=0.94. The test and retest data showed that the agreement between all the PI's were strong or almost perfect, and thus considered as very reliable and were included in the study.

Statistical analysis

Statistica software (version 13.3.721.1) was used to run statistical analyses. Descriptive data of the PI's were reported as frequencies (number of observations) and percentages, with a significance level of 5% applied ($p < 0.05$). Differences between all categorical frequencies were determined using Chi-Squared analyses (all PI's listed in Table 4.1). Four a priori proportions were decided upon as proxies of player behaviour as suggested by Brown *et al*. (2018). Specifically, player behaviour was measured by: (1) *legal* ruck cleanouts as a percentage of *all* ruck cleanouts (i.e., legal, illegal not dangerous, and illegal dangerous combined); (2) *illegal* ruck cleanouts as a percentage of *all* ruck cleanouts; (3) *illegal not dangerous* ruck cleanouts as a percentage of illegal

ruck cleanouts (i.e., illegal not dangerous and illegal dangerous combined); and (4) *illegal dangerous* ruck cleanouts as a percentage of *all* illegal ruck cleanouts. The Statistica data mining function, and a Classification and Regression Tree (CART) model, were completed with the dependable variable, namely ruck cleanout outcome (i.e., legal, illegal not dangerous, and illegal dangerous), and the independent variables being the PIs listed in Table 4.1. This model classified the best group of predictions for its outcome and established cut-off points for each PI.

4.3. Results

A total of 35 545 ruck cleanouts occurred over the five-year period (i.e., 2015 to 2019), at an average of 301 ruck cleanouts per match. The majority of ruck cleanouts (32 641; 91.8%) were legal, and the proportions of legal, illegal, illegal not dangerous, and illegal dangerous ruck cleanouts was similar for all factors including years, quarters, zonal locations, channels and match outcomes (Table 4.2). When comparing the years, the results revealed a significant (p=0.01) decrease in the number of legal and illegal dangerous ruck cleanouts, and an increase in illegal not dangerous ruck cleanouts, in 2018 and 2019 compared to the earlier years. The quarters, zonal locations, and channels did not reveal a significance difference when compared to the ruck outcomes.

Table 4.2. The number of ruck cleanouts presented as both frequency (f) and percentage (%) for legal and illegal (including dangerous and not dangerous) ruck cleanouts and various performance indicators.

Performance indicators	Legal f (%) 32 641 (91.8)	Illegal f (%) 2 904 (8.2)	Illegal not dangerous f (%) 2 676 (92.2)	Illegal dangerous f (%) 228 (7.9)
Year				
2015	7216 (93.3)	521 (6.7)	463 (88.9)	58 (11.1)
2016	7910 (93.2)	578 (6.8)	504 (87.2)	74 (12.8)
2017	5580 (93.6)	379 (6.4)	342 (90.2)	37 (9.8)
2018	6321 (89.6)	734 (10.4)	700 (95.4)	34 (4.6)
2019	5614 (89.0)	692 (11.0)	667 (96.4)	25 (3.6)
Match outcome				
Win	4272 (91.8)	382 (8.2)	372 (97.4)	10 (2.6)
Draw	1422 (93.1)	106 (6.9)	101 (95.3)	5 (4.7)
Loss	4324 (92.0)	377 (8.0)	367 (97.4)	10 (2.7)
Quarter				
Quarter 1	8536 (91.4)	798 (8.6)	741 (92.9)	57 (7.1)
Quarter 2	8076 (91.9)	708 (8.1)	651 (92.0)	57 (8.1)
Quarter 3	7847 (91.7)	708 (8.3)	645 (91.1)	63 (8.9)
Quarter 4	8182 (92.2)	690 (7.8)	639 (92.6)	51 (7.4)
Zonal location				
Zone A	8525 (91.4)	803 (8.6)	744 (92.7)	59 (7.4)
Zone B	12579 (91.5)	1105 (8.5)	1063 (91.2)	102 (8.8)
Zone C	9289 (91.6)	790 (8.4)	688 (92.2)	58 (7.8)
Zone D	2248 (92.3)	187 (7.7)	178 (95.2)	9 (4.8)
Channel				
Channel 1	5894 (92.2)	502 (7.9)	456 (90.8)	46 (9.2)
Channel 2	10332 (91.8)	928 (8.2)	853 (91.9)	75 (8.1)
Channel 3	16415 (91.8)	1474 (8.2)	1367 (92.7)	107 (7.3)

Figure 4.1(a) shows the legal and illegal ruck cleanouts as a percentage of all ruck cleanouts. The percentages ranged from 89.0% (5 614 out of 6 306) in 2019 to 94.0% (5 580 out of 5 959) in 2017 when observing illegal ruck cleanouts, regardless of whether not dangerous or dangerous ranged from 6.0% (578 out of 8 488) in 2016 to 11.0% (692 out of 6 306) in 2019. When exploring the impact of illegal dangerous and illegal not dangerous percentages further on overall illegal player behaviour and representing this as a percentage of all illegal ruck cleanouts (Figure 4.1(b), the illegal not dangerous ruck cleanout percentage ranged between 89.0% (504 out of 578) in 2016 and 96.0% (667 out of 692) in 2019. When exploring the illegal dangerous

cleanouts, the percentage ranged between 4.0% (25 out of 692) in 2019 and 13.0% (74 out of 578) in 2016.

a b

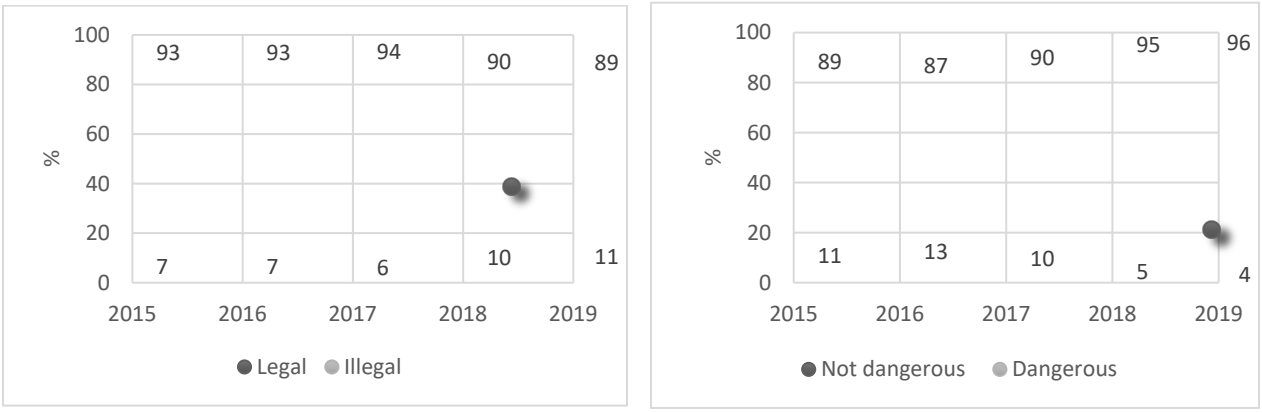

Figure 4.1. The number of illegal ruck cleanouts: (a) legal and illegal (including both not dangerous and dangerous) ruck cleanouts as a percentage of all ruck (including both legal and illegal ruck cleanouts) cleanouts per year; and (b) Illegal not dangerous and illegal dangerous ruck cleanouts as a percentage of all illegal (including both not dangerous and dangerous) ruck cleanouts per year.

When analysing *"cleaner"* arrival at the ruck for the attacking and defending teams, the results indicated that "*Cleaner 2*" for the attacking team completed significantly (p=0.02) more total cleanouts, legal cleanouts, and illegal (both dangerous and not dangerous) cleanouts when compared to the other attacking team *"cleaner"* activities (Table 4.3). When looking at the defending team, "*Cleaner 1*" was responsible for executing significantly (p=0.01) more total cleanouts, legal cleanouts, and illegal (not dangerous) cleanouts when compared to the other defending team *"cleaners"*. When analysing the ruck cleanout techniques used by the attacking and defending teams, the attacking team's "*protection*" technique revealed significant results (p=0.02) for legal ruck cleanouts. "*Clearing and protecting*" technique utilised during match play was significantly (p=0.04) for illegal ruck cleanouts both dangerous and not dangerous when compared to other cleanout techniques. When delving into the defending team, the "*jackal*" technique was executed statistically significantly ($p \leq 0.00$) more legal cleanouts when compared to the other defending ruck cleanout activities. The "*early counter ruck*" technique was responsible for significantly (p=0.02) more illegal (dangerous) ruck cleanouts (Table 4.3).

Table 4.3. The number of illegal ruck cleanouts, presented as both frequency (f) and percentage (%) for illegal dangerous and illegal not dangerous ruck cleanouts and various other performance indicators.

Performance indicators	**Legal f(%)**	**Illegal f(%)**	**Illegal not dangerous f(%)**	**Illegal dangerous f (%)**
	32 641 (91.8)	**2 904 (8.2)**	**2 676 (7.5)**	**228 (0.6)**
		Attacking team		
Frequency	2 3305 (90.1)	2 552 (9.9)	2 366 (92.7)	186 (7.3)
Cleaner arrival number				
Cleaner 1	4654 (87.0)	694 (13.0)	673 (97.0)	21 (3.0)
Cleaner 2	**7644 (86.1) ***	**1236 (13.9) ***	1128 (91.3)	108 (8.7)
Cleaner 3	6748 (93.2)	494 (6.8)	457 (92.5)	37 (7.5)
Cleaner 4	3146 (96.6)	110 (3.4)	93 (84.6)	17 (15.5)
Cleaner 5	912 (98.6)	13 (1.4)	10 (76.9)	3 (23.1)
Cleaner 6	201 (97.6)	5 (2.4)	5 (100.0)	0 (0)
Cleaner technique				
Protecting	**17131 (96.4) ***	640 (3.6)	629 (98.3)	11 (1.7)
Clearing and protecting	5753 (78.2)	**1603 (21.8) ***	**1445 (90.1) ***	**158 (9.9) ***
Clearing	415 (57.5)	307 (42.5)	290 (94.5)	17 (5.5)
Protecting and clearing	6 (75.0)	2 (25.0)	2 (100.0)	0 (0)
		Defending team		
Frequency	9336 (96.4)	352 (3.6)	310 (88.1)	42 (11.9)
Cleaner arrival number				
Cleaner 1	**5364 (96.9) ***	171 (3.1)	**167 (97.7) ***	4 (2.3)
Cleaner 2	1925 (96.1)	78 (3.9)	59 (75.6)	19 (24.4)
Cleaner 3	1020 (95.4)	49 (4.6)	45 (91.8)	4 (8.2)
Cleaner 4	639 (95.2)	32 (4.8)	25 (78.1)	7 (21.9)
Cleaner 5	287 (94.1)	18 (5.9)	12 (66.7)	6 (33.3)
Cleaner 6	101 (96.2)	4 (3.8)	2 (50.0)	2 (50.0)
Cleaner technique				
Jackal	**5311 (97.3) ***	**147 (2.7) ***	**143 (97.3) ***	4 (2.7)
Early counter ruck	3522 (95.7)	**158 (4.3) ***	**125 (79.1) ***	**33 (20.9) ***
No pressure	355 (92.2)	30 (7.8)	30 (100.0)	-
Late counter ruck	148 (89.7)	17 (10.3)	12 (70.6)	5 (29.4)

*Note: * = statistically significant ($p \leq 0.05$) when comparing illegal not dangerous and illegal dangerous ruck cleanouts to cleaner arrival and technique*

Table 4.4. The number of illegal ruck cleanouts types as both frequency (f) and percentage (%) for illegal dangerous and illegal not dangerous.

Types of illegal cleanouts	Illegal not dangerous f (%) f=2 676 (92.1%)	Illegal dangerous f (%) f=228 (87.9%)
Not supporting own body weight	**2498 (99.4) ***	15 (0.6)
Joining the ruck from an offside position	68 (100.0)	0
Shoulder charge	18 (37.5)	30 (62.5)
Contact above the shoulder	18 (34.6)	34 (65.4)
Side entry	53 (100.0)	0
Cleaning a player not involved in ruck	2 (100.0)	0
Not grasping	19 (90.5)	2 (9.5)
Neck roll	0	**147 (100.0) ***

*Note: * = statistically significant ($p \leq 0.05$) when comparing illegal not dangerous and illegal dangerous ruck cleanouts to the types of illegal cleanouts.*

Table 4.4 present the rucks for illegal not dangerous and illegal dangerous ruck cleanouts. Table 4.4 shows that of the 2 904 illegal ruck cleanouts, most of the not dangerous types were "*not supporting own body weight*" (f=2 498; 99. 4%), which was significantly (p=0.01) greater when compared to the other types of illegal not dangerous cleanouts. The remaining types of illegal not dangerous infringements were: "*joining the ruck from an offside position*" (f=68; 100.0%); and "*side entry*" (f=53; 100.0%). For the illegal dangerous types of ruck cleanouts, the majority were "*neck roll*" (f=147; 100.0%), which was significantly (p=0.02) greater than the other illegal dangerous ruck cleanouts. The remaining illegal dangerous types were: "*contact above the shoulder*" (f=34; 65.4%) and "*shoulder charge*" (f=30; 62.5%).

The importance plot revealed that the *cleaner* technique (1.0) and year (0.3) were the best predictors classifying the outcome of the current CART model. The results in Table 4.5 indicate that a 5.0% increase in legal ruck cleanout outcomes can be predicted when the attacking cleaner "*protects the ball*" and the defending team cleaner "*jackals*" or applies "*no pressure*". However, the largest reduction (from 92.0% to 77.0%) in legal ruck cleanouts, and an increase in illegal not dangerous (7.0% to 21.0%) ruck cleanouts were evident in 2018 and 2019, and when the attacking cleaner executed the following techniques: "*clearing*", "*clearing and protecting*", and "*protecting and clearing*", and the defending cleaner executed the following techniques: "*early counter ruck*" and "*late counter ruck*".

Table 4.5. Classification and Regression Tree (CART) of all ruck cleanouts with ruck cleanouts outcome (legal 92%; illegal not dangerous 7%; illegal dangerous 1%) as the dependant variable presented as a percentage (%).

Binary trees	Terminal nodes	Predictive values for ruck cleanout outcome
Tree Level 1	*Attacking cleaner technique*: protecting the ball. *Defending cleaner technique*: jackal and no pressure.	Legal: increased by 5% (97%). Illegal (not dangerous): reduced by 5% (2%). Illegal (dangerous): reduced by 1% (0%).
Tree Level 2	*Attacking cleaner technique*: clearing and protecting and protecting and clearing. *Defending cleaner technique*: early counter ruck, late counter ruck. *Year*: 2015, 2016 and 2017.	Legal: reduced by 6% (86%). Illegal (not dangerous): increased by 5% (12%). Illegal (dangerous): increased by 1% (2%).
Tree Level 3	*Attacking cleaner technique*: clearing, clearing and protecting and protecting and clearing. *Defending cleaner technique*: early counter ruck, late counter ruck. *Year*: 2018 and 2019.	Legal: reduced by 15% (77%). Illegal (not dangerous): increased by 13% (21%). Illegal (dangerous): no change.

4.4. Discussion

The major findings were that: 1) 91.8% of the ruck cleanouts were deemed legal and 92.2% of the illegal ruck cleanouts were not dangerous, 2) the attacking team was responsible for more legal ruck cleanouts (90.1%), 92.7% illegal not dangerous, and 0.7% illegal dangerous compared to the defending teams legal (96.4%), illegal not dangerous (88.1%), and illegal dangerous (11.9%) ruck cleanouts; 3) for the attacking team, "*clearing and protecting*" accounted for 90.1% of the illegal but not dangerous ruck cleanouts, compared with the defending team, the "*jackal*" accounted for 97.3% of the illegal dangerous ruck cleanouts; and 4) The majority of the illegal not dangerous ruck cleanouts were "*not supporting own body weight*" and the illegal dangerous cleanouts were "*neck roll*". To the researchers' knowledge, this is the first study that has investigated legal and illegal (both dangerous and not dangerous) cleanouts at the ruck to assess player behaviour during match play in elite youth rugby. The study by Kraak *et al*. (2019) investigated the non-sanctioning of illegal dangerous and not dangerous ruck cleanouts.

The rate of illegal ruck cleanouts compared to all ruck cleanouts can be viewed as a metric of player behaviour. The current study indicated that player behaviour worsened during the 2018 and 2019 rugby seasons. Although one could argue that the results are not direct "metrics" of player behaviour, they were chosen because they have practical relevance to rugby stakeholders, to whom this study's results must be disseminated. The findings of the current study are concerning from an injury prevention perspective because 2 676 not dangerous illegal ruck cleanouts still pose a high injury risk to players involved in rucks. Although only 228 illegal cleanouts were deemed dangerous, anyone of these cleanouts could have led to severe injury. This reasoning is also

consistent with BokSmart's adopted goal of "Vision Zero" - eliminating all serious injuries from the game (Brown *et al*., 2017). Players are required to follow the laws of the game assigned by World Rugby during training and match-play to allow players to play within the spirit of the game and more importantly to protect the welfare of players (Colomer *et al*., 2020).

Securing possession of the ball is a fundamental aspect of attack in rugby where the aim is to score points and subsequently win matches. Because of the large increase in rucks and ruck contents during match-play it has become an important facet of play for attacking and defending teams. The current study revealed that the techniques used by the attacking team cleaner were predominantly "*protecting*" and "*clearing and protecting"*. When an attacking player arrives at the tackle, when the ball carrier is on the ground, the player must assess the situation and make decisions. "*Protecting*" is when the cleaner arrives at the tackle and there is no pressure from the defending team, so the player goes into a strong position over the ball to prevent oncoming defensive cleaners accessing the ball. However, this could also be the cause of the high number of players going off their feet, as revealed in the current study. The second technique used by the attacking team player is when the cleaner clears the defending threat from the ruck and then goes into a strong position to protect the ball. The techniques predominately used by the defensive cleaners was the *"jackal"* and "*early counter ruck*". The study by Wheeler *et al*. (2013) revealed a similar trend. The study revealed the *"jackal"* and *"early counter ruck"* were the techniques used at a ruck by the defensive teams to win turnovers (39.0% and 60.0%, respectively) during the 2011 Super Rugby tournament. "*Early counter rucks*" were also effective at turning over possession when the ruck contests occurred in the wide attacking channels (18.0% of turnovers), whilst a "*jackal*" was used at ruck contests occurring in central field areas (13.0% of turnover). The study by Wheeler *et al*. (2013) further revealed that the "*early counter ruck*" led to 17.0%, and the "*jackal*" 7.0%, of the infringements, respectively. Players fulfilling a defensive role in the ruck at the time of the attack are more susceptible to concussive impacts. It may, therefore, be useful to incorporate a coaching emphasis on 'maintaining awareness' for players engaging defensively during a ruck. (Hendricks *et al*., 2016).

The findings of the current study indicate that the attacking teams arriving players engaged in more illegal ruck cleanouts when compared to the defending team. A similar trend was evident in the studies of Kraak *et al*. (2019) and Mitchell and Tierney (2020). The study by Kraak *et al*. (2019) found that the attacking team accounted for 90.0% (1 895 of 2 111) of the total illegal ruck

cleanouts at an average of 16 per match. In the afore-mentioned study the attacking team contributed 70.0% (340 of 486) of the total infringements. A typical game situation on attack could be as follows: after the initial collision and ball placement by the carrier, the first attacking player arriving has to clear the first defender away from the ball carrier and the second attacking arriving player has to secure the possession along with engaging the additional defenders as they arrive to support the first defender (Kraak & Welman, 2014). A possible reason for the infringing rate by the attacking team could be because of: (a) the ball carrier is not dominating the collision and is not presenting the ball in an effective position (Hendricks *et al*., 2018), therefore, the arriving player must use an illegal technique to try and retain possession; (b) the attacking teams arriving players reaction time is slow from fatigue due to the prior physical activity, and therefore, arrive late at the collision (Kraak *et al*. 2019); (c) poor decision-making and assessment of the situation; (d) poor ruck cleaning techniques used in the latter period of the match because of fatigue (Burger *et al*., 2018); and (e) the defending team might be infringing already because the attacking team has no other option but to use illegal techniques in order to retain possession (Kraak *et al*. 2019). Studies by Wheeler *et al*. (2010) and Kraak and Welman (2014) identified that it is obvious that players must execute specific actions and techniques in order to retain (attacking team) or regain (defending team) possession of the ball at the ruck.

The current study revealed that "*not supporting own body weight*" was the type of not dangerous illegal ruck cleanouts that occurred the most during match-play. This finding is in agreement with the findings of Kraak *et al*. (2019) who also found that "*not supporting own body weight*" occurred the most out of all the illegal not dangerous ruck cleanouts during the 2018 Super Rugby tournament. However, a similar trend was not evident in the study by Mitchell and Tierney (2020) during the 2019 Rugby World Cup. Their study revealed that "*head and shoulders below hips*" was considered the infringement that occurred the most. A possible reason why players might not support their own body can be two-fold: 1) the players arrives late and the defending teams cleaner might have already protected the ball, and therefore, the player needs to perform an illegal action to try and protect the ball; and 2) the first arriving player might execute an illegal action, and therefore, the infringing player needs to go low in order to clean the player from the ball. By going low there is the possibility and risk that the infringing player might execute a "*neck roll*" (Barkell *et al*., 2018), which is considered the most dangerous ruck cleanout. "*Not supporting own*

body weight" and "*neck rolls*" could cause major injuries because of the increase in size and length of players that participate in the Craven Week tournament (Brown *et al*., 2012).

Practical applications

The illegal (not dangerous and dangerous) activities of player behaviour need to be addressed, emphasised, and improved through correct and effective technique drills during training, changing player behaviour, improving decision-making, which could also be minimized by the on-field referee by focusing on these "*going off your feet*" and "*neck roll*", especially the neck roll because it could cause serious life-threatening injuries (Emery *et al*., 2015). Effective execution of techniques depends on player's physical conditioning and their tactical awareness (Hendricks *et al*., 2012; Hendricks & Lambert, 2014; Sewry *et al*., 2015). Coaches can also improve player techniques by designing a technical training session that assess the technical skill level of the players (Hendricks *et al*., 2018). This can be executed by using the two-on-two contact drill explained by Den Hollander *et al*. (2019). The study of Den Hollander *et al*. (2019) found that senior level players scored higher than academy players in technical assessments, highlighting that in order for players to progress safely through the levels of competition they need to develop the proper ruck technique. Better techniques will improve performance and decrease injury risk (Den Hollander *et al*., 2019), as well as appropriate attitudes towards injury prevention and management, which should be encouraged and implemented by the coach (Whatman *et al*., 2018). However, these attitudes are dependent on how compliant the players are (Steffen *et al*., 2013). Coaches play a critical role in younger player's injury prevention and management because severe injuries have the potential to cause chronic pain and disability in adulthood, which negatively impacts quality of life (Emery *et al*., 2015).

With the Craven Week tournaments players do not have a lot of preparation time, and therefore, this could result in more illegal actions because of incorrect techniques. According to Hendricks *et al*. (2015), verbal instruction and demonstration of correct and safe techniques are the most effective coaching methods for contact events. Therefore, coaching the ruck should follow the same principle as the tackle because they are both contact events. The same key factors that are applied to a tackle can also be applied to the ruck. In order to make a legal safe ruck and cleanout players need to have correct timing, momentum coming into a ruck, head and body position (Boucher, 2017).

Subsequently, a call for the development of a contact-skill programme was made (Hendricks *et al*., 2016). The results of the current study provide evidence to assist the design of such a programme and highlight techniques that should be emphasised during training. Furthermore, the contact techniques associated with success in the current study are recommended for other standards of play. Ruck drills should include the initial tackle, fight for dominance, correct ball placement, and correct and safe clearing techniques in the same drill. By including all these events it will assist players with decision-making skills during practise, which will be carried over to a match situation (Kraak *et al*., 2019). Video analysis could also be very beneficial and should be included in training sessions. Players should be able to have access to these videos and after every match should do a self-reflection of their performance, as well as the team's performance. The self-reflection is a nice way for the player to recognise their mistakes and poor player behaviour and reflect on what an ideal situation should look like. By looking at the team's performance as a whole can help each player recognise the mistakes, illegal actions, and how the team can improve as a whole by focusing on improving performance and focusing on player safety at the same time. According to Hendricks *et al*. (2018) more work is required to improve the understanding of relationships amongst technique, fatigue, tactics, and performance, and coaches should consider these factors when designing and developing contact-technique training.

Limitations and future research directions

The camera angle at times caused a limitation in the sense that it was difficult to see the players' actions during a ruck. Another limitation was that the current study only analysed one youth competition, and therefore, the findings of the study cannot be generalised across all youth rugby levels. Future studies should investigate the ruck cleanouts in other elite competitions, as well as at community level and should also include factors, such as final log position after competition of the competition and the nationality of teams. Further research could also use eye trackers during ruck cleanout training to investigate the players gaze and what they focus on during a ruck. Researchers can also use questionnaires in order to go into more detail regarding player behaviour.

4.5. Conclusion

The current study of player behaviour in youth rugby found that 92.1% of illegal tackles were not dangerous. Although being a low proportion, the illegal dangerous ruck cleanouts remain a concern for stakeholders from an injury prevention perspective. Because of the evolving nature of the game

the amount of ruck cleanouts carried out in rugby matches will not decrease, therefore, focus should be placed on how cleanouts are carried out by players during the match. To aid injury prevention efforts, future studies should explore why players execute illegal ruck cleanouts as per the laws of the game. Additional interventions need to be targeted at coaches and players to improve the shortcomings. If players are not playing within the laws and prevention strategies, the effectiveness of injury prevention programmes will be reduced. Since illegal cleanouts are dangerous, the data from the current study reinforces the importance of coaching correct techniques, correcting player behaviour and continued strict enforcement of illegal not dangerous and illegal dangerous cleanouts during training and matches. Because of limited research on investigating the legal, illegal not dangerous and illegal dangerous cleanouts during match-play, it is important to expand the area of research so that the game is safer for all involved in order to assist in decreasing injury incidence.

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CHAPTER FIVE

RESEARCH ARTICLE TWO

SANCTIONING OF ILLEGAL RUCK CLEANOUTS BY ON-FIELD REFEREES DURING ELITE YOUTH RUGBY UNION TOURNAMENTS

Chapter Five is included herewith in accordance with the author guidelines provided for the esteemed Journal of Sports Sciences (Appendix B). However, to provide an orderly and well-drafted product for this thesis, the article has been edited to represent an actual published article as it would appear in the journal. However, this does not imply that the article has been accepted or will be accepted for publication. Consequently, the referencing style used in this chapter may differ from styles used in other chapters of the thesis.

Title page

Title: Sanctioning of illegal ruck cleanouts by on-field referees during elite youth rugby union tournaments

Field of study: Sport Science (Performance analysis)

Running title: Non-sanctioning of illegal ruck cleanouts

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Sanctioning of illegal ruck cleanouts by on-field referees during elite youth rugby union tournaments

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Abstract

To improve player behaviour and decrease the risk of injury on-field referees need to enforce the laws of rugby more strictly during match-play. The current study aimed to investigate the accuracy of referee decision-making regarding sanctioning and not-sanctioning illegal ruck cleanouts by using Nacsport software (version: Scout Plus, Spain: 2008). A total of 118 games were analysed. Over five years from 2015 to 2019, 10 883 rucks and 35 545 cleanouts were analysed. Of the ruck cleanouts, 2 676 were illegal not dangerous and 228 were illegal dangerous. The main finding was that the on-field referees did not sanction 95.0% (2 548 out of 2 676) of illegal mot dangerous cleanouts and 95.0% (217 out of 228) dangerous cleanouts. The attacking team were responsible for more illegal not dangerous and illegal dangerous cleanouts, however, they were penalised less when compared to the defending team. Most illegal not dangerous and illegal dangerous ruck cleanouts not sanctioned by the referees were "*not supporting own body weight*" (96.7%, f=2 416) and "*neck roll*" (95.2%, f=140). Another worrying result of the study is out of all the non-sanctioned illegal (not dangerous and dangerous combined) "*no obstruction*" occurred 85.9% (2 374 out of 2 765) when the referee had to sanction the infringement. The findings of the current study provide rugby referee stakeholders with data that suggests that the officiating of the ruck area needs to be more seriously recognised and referee decision-making interventions need to be implemented at this development referee level.

Keywords: *Referee behaviour, injury prevention, elite youth rugby, performance analysis, surveillance, decision-making*

5.1. Introduction

Rugby is a contact sport and because of its physical nature it has a high injury incidence compared to most other team sports (Quarrie & Hopkins, 2008; Fuller *et al*., 2010; Hendricks & Lambert,

2010; McIntosh *et al*., 2010). The majority of injuries in schoolboy rugby are caused by tackles (57.0% of injuries) and rucks (16.0% of injuries) (Palmer-Green *et al*., 2013). At senior level time-loss match injuries occurred at a rate of 94 injuries per 1 000 player exposure hours during the 2019 Currie Cup Tournament (Starling *et al*., 2020), compared to 16 injuries per 1 000 player exposure hours at the under 18 Craven Week and 22 injuries per 1 000 player exposure hours at the under 18 Academy Week during the 2018 South African Rugby Union (SARU) Youth Week Tournaments (Starling *et al*., 2019). To date only two articles have been published on sanctioning at ruck cleanouts (Kraak *et al*., 2019; Mitchell & Tierney, 2020). However, the afore-mentioned studies investigated ruck cleanouts at professional and not schoolboy level. Very little research has been conducted on rugby officials and their direct influence on rugby safety (Brown *et al*., 2018; Kraak *et al*., 2019), with no research conducted at school level on rugby officials' law application and implementation during ruck cleanouts.

Referees and match officials play a major role in preventing injuries at all levels of rugby by enforcing the laws, making the game as safe as possible and by sanctioning all forms of illegal, dangerous acts and foul play (Mascarenhas *et al*., 2005; Spitz *et al*., 2016; Burger *et al*., 2017). Referees are required to keep up with the speed of the game, make observations, interpret the information, make high pressure rapid decisions within seconds, and then make an informed decision (Jones *et al*., 2002). Therefore, referees require perceptual-cognitive abilities to recognise and process the most important information on the field in order to make quick and accurate decisions (Martenuik, 1976). Emmonds *et al*. (2015) observed the lowest accuracy from referees in the last 15 minutes of the game. This suggests that physical and/or mental fatigue occurs in the final stages of the match, which may result in a decrease in call accuracy and the decision-making abilities of referees.

To keep up with the game and players, referees need to be physically fit in order to make accurate decisions and apply the laws of the game correctly (Suarez-Arrones *et al*., 2013; Nazarudin *et al*., 2015; Bester *et al*., 2019). Accurate decision-making ability is the most important role of a referee because it ensures fair play, the safety of players and upholds the integrity of the game (Helsen & Bultynck, 2004). Video-based performance analysis (PA) can be used by referees to analyse the match and any relevant biomechanical indicators (Hughes & Franks, 2007). By using the video-based PA technique, referees are able to analyse their individual performance, on-

field positioning and decision-making accuracy during a match, which acts as a learning tool to improve their on-field performance.

The study by Mitchell and Tierney (2020) analysed a total of 898 rucks during the knockout stages of the 2019 Rugby World Cup of which 37.7% (f=339) seemed to involve illegal player actions. 79.9% of rucks that involved illegal player actions were not penalised with most infringements being "*head and shoulders below hips*" 33.5% (f=163), "*not supporting own body weight*" 13.0% (f=63) and "*offside*" 10.5% (f=51). The attacking teams were responsible for 70.0% (f=340) of all ruck infringements despite being penalised less than the defending team. The afore-mentioned study concluded that a high number of infringements occurred at rucks and went unsanctioned (Mitchell & Tierney, 2020). Kraak *et al*. (2019) analysed a total of 22 281 ruck cleanouts during the 2018 Super Rugby competition of which 2 111 (9.0%) were deemed illegal according to the 2018 Laws of the Game. Of the illegal cleanouts (f=2 111), 93.0% (f=1 953) were not sanctioned by the on-field referee although 51.0% (f=1 087) were considered dangerous. The on-field referee did not sanction 90.0% (1 804 out of 1 953) of the illegal ruck cleanouts performed by the attacking team in order to allow more continuity of the game (Kraak *et al*., 2016, 2017). The study performed by Brown *et al*. (2018) investigated the non-sanctioning of illegal tackles during the under 18 Craven Week Tournaments between 2011 and 2015. Their main finding was that out of a total of 12 216 tackles, 113 were deemed as illegal with 59.0% (67 out of 113) not being sanctioned appropriately by the on-field referee. It is a great concern when referees do not accurately and consistently sanction illegal and/or foul play because there is a high risk that it could escalate or continue and potentially lead to serious injury.

The current study focused on decision-making around ruck cleanouts by on-field referees at the SARU under 18 Craven Week Tournaments between 2015 and 2019. Referees' on-field behaviour regarding rugby safety decision-making during ruck cleanouts was specifically examined. The findings of the current study may lead to the development and implementation of further injury prevention strategies or interventions to make the game safer for all the role-players involved. The aim of this study was, therefore, to investigate referee decision-making accuracy at the rucks regarding their sanctioning and not sanctioning illegal ruck cleanouts.

5.2. Methodology

Televised video recordings of 118 matches during the 2015 to 2019 South African Rugby Union (SARU) under 18 Craven Week Tournaments were analysed. Ethical approval was obtained from the Research Ethics Committee: Human Research, Stellenbosch University (REC-2019-10416). The video recordings were supplied by the SARU technical department. Exclusion criteria were any vague footage where the angle was too far, the image was blurry, or the event was unable to observe because of players obstructing the view.

All the video recordings were analysed using Nacsport software (version: Scout Plus, Spain: 2008). The Nacsport video software allows for a specific event to be coded and then reflected as performance indicators (PI's). During the coding, the coders were at liberty to pause, rewind and to watch the footage in slow motion. Each ruck cleanout was coded according to the PI's and operational definitions identified and compiled by the panel of specialists displayed in Table 5.1. The PI's and operational definitions for the purpose of this study were validated beforehand using methods prescribed by O'Donoghue (2009) and Watson *et al*. (2017). Before the coding commenced a "gold standard" was set by an international referee using the definitions of the 2020 World Rugby (WR) Laws of the Game, as well as analysing a match with the coder using the same methodology applied by Brown *et al*. (2018) and Kraak *et al*. (2019).

The reliability of the coded ruck cleanouts was tested using intra- and inter-rater reliability and was tested prior to the start and again once coding was complete (Gratton & Jones, 2004). The primary researcher coded a full match before commencement of the data collection and then re-coded the same match 7 days later to test for intra-rater reliability. An external coder coded the same match, and then recoded the match again 7 days later for inter-rater reliability. After the initial coding, the primary researcher, and an external coder re-coded n=20 matches that were randomly selected for the intra- and inter-rater reliability. The intra- and inter-rater reliability for before and after the coding was determined using the Intraclass Correlation Coefficient (ICC) of the test and retest data. Intra- and inter-rater agreement were interpreted as follows: poor (<0.20), fair (0.30 to 0.40), moderate (0.50 to 0.60), strong (0.70 to 0.95) and almost perfect (>0.95) (Gratton & Jones, 2004). The results for the intra-coder reliability for the different stages of the research was as follows: before commencement of coding r=0.97 (almost perfect) and after coding 0.95 (almost perfect). The total inter-coder reliability for the external coder before commencement

of coding was r=0.96 (almost perfect) and after coding r=0.94 (strong). The total inter-coder reliability for the international referee after the coding was r=0.94 (strong).

Descriptive data was reported as frequencies (number of observations) and percentages. Differences between categorical frequencies were determined by using a Chi-Square analysis. Some indicators are expressed as percentages, which according to Hughes and Bartlett (2002) provides a more accurate analysis of team performance. *A priori* proportions were decided upon as proxies for measuring referee behaviour, similar to that used by Kraak *et al*. (2019) and Brown *et al*. (2018). Referee behaviour was measured by (a) *sanctioned illegal* ruck cleanouts as a percentage of *all illegal* ruck cleanouts (not dangerous and dangerous combined); (b) *not sanctioned illegal* ruck cleanouts as a percentage of *all illegal* ruck cleanouts; (c) *sanctioned illegal not dangerous* ruck cleanouts as a percentage of *all* ruck cleanouts (legal and illegal combined); (d) *non-sanctioned illegal not dangerous* ruck cleanouts as a percentage of *all* ruck cleanouts (legal and illegal combined); (e) *sanctioned illegal dangerous* ruck cleanouts as a percentage of *all illegal* ruck cleanouts; (f) *non-sanctioned illegal dangerous* ruck cleanouts as a percentage of *all illegal* ruck cleanouts; (g) *sanctioned illegal dangerous* ruck cleanouts as a percentage of *all* ruck cleanouts (legal and illegal combined); and (h) *non-sanctioned illegal dangerous* ruck cleanouts as a percentage of *all* ruck cleanouts (legal and illegal combined).

Table 5.1: The performance indicators and operational definitions used in the study

Performance indicator	Operational definition
Ruck. (World Rugby, 2020)	The ruck is defined as a phase of play where one or more players from each team, who are on their feet and in physical contact, close around the ball, which is on the ground.
Ruck cleanout. (Kraak *et al*., 2019)	A cleanout during a ruck is when the players contesting in the ruck make contact, drive with the legs and clear the opposition off or away from the ball in an attempt to either turnover or maintain possession.
Ruck cleanout outcome. (World Rugby, 2020)	Legal: according to the 2020 WR law book. Illegal: according to the 2020 WR law book.
Illegal ruck cleanout outcomes. (Kraak *et a*l., 2019)	Illegal dangerous ruck cleanout-action was deemed dangerous if the action of the player could lead to injury of (a) himself), (b) own players and (c) opposition players.
Match-time period. (Brown *et al*., 2018)	Quarter 1: 0 to 17.5 minutes; Quarter 2: 17.5 to 35> minutes; Quarter 3: 35 to 52.5 minutes; and Quarter 4: 52.5 to 70> minutes.
Zonal locations. (Van Rooyen *et al*., 2010)	Zone A: Attacking area between 22m area and the try line. Zone B: Attacking area between 22m area and halfway line. Zone C: Defence area between 22m area and the halfway line. Zone D: Defence area between 22m area and the try line.

Channels. (Den Hollander *et al*., 2016; Hendricks *et al*., 2018)	Channel 1: From left touchline to 15m lines. Channel 2: In between the 15m lines. Channel 3: 15m to the right touchline.
Attacking team. (Kraak & Welman, 2014)	The team in possession of the ball.
Defending team. (Kraak & Welman, 2014)	The team not in possession of the ball.
Types of illegal ruck cleanouts. (World Rugby, 2020)	*Neck roll*: A cleaner must not grasp an opposition player around the neck area to clean out. *Not supporting own body weight*: A player cleaning out a ruck must be on his feet. *Joining the ruck while in an offside position*: A player cleaning at the ruck may not do so while in an offside position. Non-participants at the breakdown must be behind the hindmost foot of the last player in their side of the ruck. *Shoulder charge*: A player must not charge into a ruck. Charging includes any contact made without use of the arms, or without grasping a player. *Side entry*: A cleaner must join alongside but not in front of the hindmost player. *Not grasping on teammate when cleaning*: A player joining a ruck must bind on a teammate or an opponent, using the whole arm. The bind must either precede or be simultaneous with contact with any other part of the body of the player joining the ruck. *Cleaning a player not involved in the ruck*: A cleaner must not take-out opposition players who are not part of the ruck. *Contact above shoulder of opposition player*: A cleaner must not make contact with an opponent above the line of the shoulders.
Arrival time of referee (within 1m of the ruck).	Early: Before the ruck has commenced. Late: After the ruck has commenced. Not in frame: the referee could not be seen because of the camera focusing in on the ruck cleanout.
Positioning of referee (static).	Behind ruck close: within 1m. Behind ruck far: 1.1m or further away. 45º at ruck close: within 1m. 45 º at ruck far: 1.1m or further away. Not in frame: the referee could not be seen because of to the camera focusing in on the ruck cleanout.
Line of positioning (dynamic).	Attacking line: standing on the attack side. Defensive: standing on the defence side. Not in frame: the referee could not be seen because of the camera focusing in on the ruck cleanout.
SInfluence of sanctioning illegal ruck cleanouts by referees.	*Players obstructing referee view (poor arrival position)*: Poor arrival position means referee cannot maintain ball vision 100% of the time. *Focus on offside line*: not managing the breakdown whilst the contest is still occurring – in other words the ball has not been won and the referee is looking at the offside line. *No obstruction* - referee is in a position where neither players nor their position is blocking the event. *Position obstructing* - referee is in a position where he/she cannot see clearly. *Not in frame*- the referee could not be seen because of the camera focusing in on the ruck cleanout.
Sanction. (World Rugby, 2020)	Penalty awarded against defending team. Penalty yellow card (YC) awarded against defending team. Penalty red card (RC) awarded against defending team. Penalty awarded against attacking team. Penalty YC awarded against attacking team.

	Penalty RC awarded against attacking team. Advantage played by the attacking team. Advantage played by the defending team.
Correctly sanctioned. (World Rugby, 2020)	Yes: according to the WR Law Book. No: according to the WR Law Book.

5.3. Results

The study revealed that a total of 35 545 ruck cleanouts occurred over the five-year period (2015 to 2019), at an average of 301 ruck cleanouts per match. Most ruck cleanouts (f=32 641; 91. 8%) were deemed legal and (f=2 904; 8.2%) were illegal. The results showed that out of the 2 904 total illegal ruck cleanouts 92.1% (f=2 676) were deemed illegal not dangerous and 7.9% (f=228) were illegal dangerous. The on-field referees sanctioned 5.0% (f=139) of the illegal ruck cleanouts, while 95.0% (f=2 765) were not sanctioned. When looking at a further breakdown of the illegal cleanouts, the illegal not dangerous ruck cleanouts 5.0% (128 out of 2 676) were sanctioned and 95.0% (2 548 out of 2 676) were not. Of the dangerous ruck cleanouts 5.0% (11 out of 228) were sanctioned and 95.0% (217 out of 228) were not.

Table 5.2 presents the proportion of sanctioned versus non-sanctioned illegal, illegal not dangerous and illegal dangerous ruck cleanouts and various PI's coded during the 2015 to 2019 Craven Week Tournaments. When looking at sanctioning and not sanctioning of all illegal ruck cleanouts (not dangerous and dangerous), the current study indicates a significant increase (p=0.03) from 2015 to 2016 and a significant decrease (p=0.02) from 2016 to 2017 for the sanctioned illegal ruck cleanouts. The sanctioned illegal ruck cleanouts indicated a significant decrease (p=0.03) from quarter 2 to 3 and a significant increase (p=0.04) from quarter 3 to 4. For non-sanctioned ruck cleanouts, the study indicated a significant decrease (p=0.02) from 2016 to 2017 and a significant increase (p=0.04) from 2017 to 2018. The non-sanctioned illegal ruck cleanouts indicated a significant decrease (p=0.03) from quarter 1 to 2. The majority of the sanctioned and not sanctioned illegal ruck cleanouts took place in Zone B and Channel 3.

Table 5.2 The proportion of sanctioned versus non-sanctioned illegal (not dangerous and dangerous) ruck cleanouts and various performance indicators coded during the 2015 to 2019 Craven Week tournaments

Performance indicators	Illegal		Illegal not dangerous		Illegal dangerous	
	Sanctioned f (%)	Not sanctioned f (%)	Sanctioned f (%)	Not sanctioned f (%)	Sanctioned f (%)	Not sanctioned f (%)
Year						
2015	21 (4.0)	500 (96.0)	19 (4.1)	444 (95.9)	2 (3.5)	56 (96.6)
2016	**37 (6.4)****	541 (93.6)	32 (6.4)	472 (93.7)	**5 (6.8)****	69 (93.2)
2017	**7 (1.9)***	**372 (98.2)***	**5 (1.5)***	**337 (98.5)***	**2 (5.4)***	**35 (94.6)***
2018	**41 (5.6)****	**693 (94.4)****	**40 (5.7)****	**660 (94.3)****	1 (2.9)	33 (97.1)
2019	33 (4.8)	659 (95.2)	32 (4.8)	635 (95.2)	1 (4.0)	24 (96.0)
Quarter						
Quarter 1	43 (5.4)	755 (94.6)	38 (5.1)	703 (94.9)	5 (8.8)	52 (91.2)
Quarter 2	41 (5.8)	**667 (94.2)***	39 (5.99)	**612 (94.0)***	**2 (3.5)***	55 (96.5)
Quarter 3	**24 (3.4)***	684 (96.6)	**23 (3.6)***	622 (96.4)	1 (1.6)	62 (98.4)
Quarter 4	**31 (4.5)****	659 (95.5)	28 (4.4)	611 (95.6)	3 (5.9)	48 (94.1)
Zone						
Zone A	28 (3.5)	776 (96.5)	24 (3.2)	721 (96.8)	4 (6.8)	55 (93.2)
Zone B	60 (5.2)	1106 (94.9)	56 (5.3)	1008 (94.7)	4 (3.9)	98 (96.1)
Zone C	34 (4.6)	713 (95.5)	31 (4.5)	658 (95.5)	3 (5.2)	55 (94.8)
Zone D	17 (9.1)	170 (91.0)	17 (9.6)	161 (90.5)	0	9 (100.0)
Channel						
Channel 1	26 (5.2)	476 (94.8)	25 (5.5)	431 (94.5)	1 (2.2)	45 (97.8)
Channel 2	41 (4.5)	887 (95.6)	39 (4.6)	814 (95.4)	2 (2.7)	73 (97.3)
Channel 3	72 (4.9)	1402 (95.1)	64 (4.7)	1303 (95.3)	8 (7.5)	99 (92.5)

Note: * Significant decrease; ** Significant increase

When looking at the illegal not dangerous sanctioned ruck cleanouts the study shows a significant decrease (p=0.03) from 2016 to 2017, a significant increase (p=0.02) from 2017 to 2018, and a significant decrease (p=0.01) from quarter 2 to 3. The majority of illegal not dangerous ruck cleanouts that were sanctioned took place in Zone B and Channel 3. When exploring the not sanctioned illegal not dangerous cleanouts the study exposed a significant decrease (p=0.03) from 2016 to 2017, a significant increase (p=0.03) from 2017 to 2018, and a significant decrease (p=0.02) from quarter 1 to 2. The majority of ruck cleanouts that were not sanctioned took place in Zone B and Channel 3. When observing the illegal dangerous ruck cleanouts a significant increase (p=0.03) was observed from 2015 to 2016, a significant decrease (p=0.04) from 2016 to 2017, and a significant decrease (p=0.02) from quarter 1 to 2. The majority illegal dangerous ruck cleanouts that were sanctioned took place in Zone A and B and Channel 3. For the not sanctioned all illegal ruck cleanouts (dangerous and not dangerous combined) a significant decrease (p=0.03) was observed from 2016 to 2017. The time in the match did not indicate any significant differences for not sanctioned ruck cleanouts.

When exploring the impact of sanctioned and not sanctioned illegal not dangerous and illegal dangerous percentages across the years to represent referee behaviour as a percentage, shows the sanctioned and not sanctioned illegal ruck cleanouts as a percentage of all the illegal ruck cleanouts. The percentages for sanctioned ruck cleanouts ranged from 94.0% (37 out of 578) in 2016 to 2.0% (7 out of 379) in 2017. On the other hand, the not sanctioned illegal ruck cleanouts ranged from 94.0% (541 out of 578 & 693 out of 734) in 2016 and 2018 to 98.0% (372 out of 379) in 2017. When observing the sanctioned and not sanctioned illegal not dangerous ruck cleanouts as a percentage of all illegal ruck cleanouts the following data is revealed: the percentages for sanctioned illegal not dangerous ruck cleanouts ranged from 1.0% (5 out of 379) in 2017 to 6.0% (32 out of 578) in 2016; and the not sanctioned illegal not dangerous ruck cleanouts ranged from 82% (472 out of 578) in 2016 to 92.0% (635 out of 692) in 2019. On the other hand, the percentages for sanctioned illegal dangerous ruck cleanouts ranged from 1.0% (5 out of 379) in 2017 to 6.0% (32 out of 578) in 2016 and the not sanctioned illegal dangerous ruck cleanouts ranged from 82.0% (69 out of 578) in 2016 to 92.0% (635 out of 692) in 2019.

Table 5.3 The proportion of sanctioned versus non-sanctioned illegal not dangerous and illegal dangerous ruck cleanouts coded per attacking and defending team ruck cleanouts and various performance indicators during the 2015 to 2019 Craven Week tournaments

	Illegal not dangerous		**Illegal dangerous**	
Performance indicators	Sanctioned f (%)	Not sanctioned f (%)	Sanctioned f (%)	Not sanctioned f (%)
Attacking team				
Frequency	39 (1.7)	2327 (98.3)	8 (4.3)	178 (95.7)
Cleaner arrival number				
Cleaner 1	15 (2.2)	658 (97.8)	0	21 (100.0)
Cleaner 2	19 (1.7)	**1109 (98.3)***	7 (6.5)	**101 (93.5)***
Cleaner 3	4 (0.9)	453 (99.1)	1 (2.7)	36 (97.3)
Cleaner 4	0	93 (100.0)	0	17 (100.0)
Cleaner 5	1 (10.0)	9 (90.0)	0	3 (100.0)
Cleaner 6	0	5 (100.0)	0	0
Cleaner technique				
Protecting	14 (2.2)	615 (97.8)	0	11 (100.0)
Clearing and protecting	**19 (1.3)***	**1426 (98.7)***	8 (5.1)	**150 (94.9)***
Clearing	6 (2.1)	284 (97.9)	0	17 (100.0)
Protecting and clearing	0	2 (100.0)	0	0
Defending team				
Frequency	89 (28.7)	221 (71.3)	3 (7.1)	39 (92.9)
Cleaner arrival number				
Cleaner 1	**49 (29.3)***	**118 (70.7)***	2 (50.0)	2 (50.0)
Cleaner 2	17 (28.8)	42 (71.2)	0	**19 (100.0)***
Cleaner 3	9 (20.0)	36 (80.0)	0	4 (100.0)
Cleaner 4	10 (40.0)	15 (60.0)	1 (14.3)	6 (85.7)
Cleaner 5	4 (33.3)	8 (66.7)	0	6 (100.0)
Cleaner 6	0	2 (100.0)	0	2 (100.0)
Cleaner technique				
Jackal	**49 (34.3)***	**94 (65.7)***	2 (50.0)	2 (50.0)
Early counter ruck	35 (28.0)	**90 (72.0)***	0	**33 (100.0)***
No pressure	1 (3.3)	29 (96.7)	0	0
Late counter ruck	4 (33.3)	8 (66.7)	1 (20.0)	4 (80.0)

*Note: * = statistically significant ($p \leq 0.05$) when comparing illegal not dangerous sanctioned vs not sanctioned and illegal dangerous sanctioned vs not sanctioned ruck cleanouts to cleaner arrival and technique*

Table 5.3 presents the attacking vs defending team ruck cleanouts per cleaner arrival and technique executed. The attacking team was responsible for 2 547 cleanouts combined with 81.0% illegal

not dangerous (f=2 366) and 7.0% dangerous (f=186) cleanouts, compared to the defending team that had a combined total of 357 of which 11.0% were illegal not dangerous (f=310) and 1.0% was dangerous (f=42). Of the 2 366 illegal not dangerous cleanouts made by the attacking team, 1.7% (f=39) was sanctioned and 98.3% (f=2 327) were not sanctioned by the on-field referee, compared to the dangerous cleanouts where 8 (4.3%) were sanctioned and 178 (95.7%) were not sanctioned. Of the 310 illegal not dangerous ruck cleanouts made by the defending team, 28.7% (f=89) were sanctioned and 71.3% (f=221) were not sanctioned by the on-field referee compared to the dangerous cleanouts where 7.1% (f=3) was sanctioned and 92.9% (f=39) was not sanctioned. When observing the illegal not dangerous ruck cleanouts of the attacking team "*cleaner 1* and *2*" went significantly unsanctioned when compared to other cleaners. When looking into the cleanout technique utilised by the player "*clearing and protection*" was sanctioned significantly (p=0.04) more compared to other techniques. The same significant (p=0.03) trend was evident for the non-sanctioned activities. When exploring the defending team, "*cleaner 1*" for both the sanctioned and non-sanctioned was significantly different (p=0.04 & p=0.03, respectively). "*Cleaner 2*" were not sanctioned the majority (p=0.04) of the time by the on-field referee. When looking into the defending player's activities the "*jackal*" was significant more sanctioned (p=0.03) and not sanctioned (p=0.04) when compared to other techniques used by the defending team players. "*Early counter ruck*" also revealed a significant difference for not sanctioned (p=0.04). When exploring the sanctioned and not sanctioned illegal dangerous ruck cleanouts for the attacking team the study revealed a statistically significant (p=0.03) difference for "*cleaner 2*" regarding the not sanctioned.

Table 5.4 Illegal not dangerous and illegal dangerous ruck cleanouts sanctioned and not sanctioned

Types of cleanouts	Illegal not dangerous		Illegal dangerous	
	Sanctioned f (%)	Not sanctioned f (%)	Sanctioned f (%)	Not sanctioned f (%)
Not supporting own body weight	**82 (3.3)***	**2416 (96.7)***	2 (13.3)	13 (86.7)
Joining the ruck from an offside position	32 (47.1)	36 (52.9)	0	0
Shoulder charge	0	18 (100.0)	2 (6.7)	28 (93.3)
Contact above the shoulder	0	18 (100.0)	0	34 (100.0)
Side entry	13 (24.5)	40 (75.5)	0	0
Cleaning a player not involved in ruck	0	2 (100.0)	0	0

Not grasping	0	19 (100.0)	0	2 (100.0)
Neck roll	0	0	**7 (4.8)***	**140 (95.2)***

*Note: *- (p≤0.05) statistically significant between sanctioned and non-sanctioned*

Table 5.4 presents the different types of illegal ruck cleanouts in proportion to all the illegal and dangerous illegal ruck cleanouts sanctioned vs. not sanctioned by the on-field referee. The following compares the sanctioning and non-sanctioning rates of the on-field referees. For the illegal not dangerous cleanouts "*not supporting own body weight*" not sanctioned (2 416 out of 2 498; 96.7%) vs. sanctioned (82 out of 2 498; 3.3%) revealed a significant difference p=0.04. When looking into the dangerous cleanouts ruck "*neck rolls*" not sanctioned (140 out of 147; 95.2%) vs sanctioned (7 out of 147; 4.8%) these results were statistically significant p=0.03. Even though not statistically significant, "*contact above shoulder*" not sanctioned (34 out of 34; 100.0%) vs sanctioned (0 out of 34; 0%) is still worrying from a referee behaviour perspective.

Table 5.5: Referee arrival time. positioning (static). positioning line and obstructing referee in proportion of sanctioned and not sanctioned illegal dangerous and illegal not dangerous ruck cleanouts

Performance indicators	**Illegal not dangerous**		**Illegal dangerous**	
	Sanctioned f (%)	Not sanctioned f (%)	Sanctioned f (%)	Not sanctioned f (%)
Referee arrival time at ruck				
Early	121 (5.1)	**2243 (94.9)***	10 (4.9)	**194 (95.1)***
Late	1 (8.3)	11 (91.7)	0	3 (100.0)
Not in frame	6 (2.0)	294 (98.0)	1 (4.8)	20 (95.2)
Positioning at ruck (static)				
45° at ruck close	110 (5.3)	**1978 (94.7)***	9 (4.8)	**177 (95.2)***
45° at ruck far	1 (7.7)	12 (92.3)	0	1 (100.0)
Behind ruck close	11 (4.0)	263 (96.0)	1 (5.0)	19 (95.0)
Behind ruck far	0	1 (100.0)	0	0
Not in frame	6 (2.0)	294 (98.0)	1 (4.76)	20 (95.2)
Positioning line at ruck				
Attacking line	**116 (5.1)***	**2173 (94.9)***	**9 (4.5)***	**191 (95.5)***
Defensive line	6 (6.9)	81 (93.1)	1 (14.3)	6 (85.7)
Not in frame	6 (2.0)	294 (98.0)	1 (4.8)	20 (95.2)

*Note: *- (p≤0.05) statistically significant between sanctioned and non-sanctioned*

When looking at the referee's arrival at the ruck it is clear from Table 5.5 at the majority of the rucks the on-field referee arrived "*early*" at the ruck, however, 94.9% 2243 out 2364 of illegal not dangerous infringement were not sanctioned this finding was statistically significant p=0.04.

When looking at the referee's arrival time at the dangerous ruck cleanouts at the majority of the rucks the referee arrived "*early*" but did not sanctioned 94.6% (194 out of 204) the infringements this finding was statistically significant p=0.02. When exploring the referees positioning at the ruck the referees preferred the "*45° at ruck close*" position. However, this position was also associated with a high error rate for both illegal not dangerous and illegal dangerous and these findings were statistically significant. The referees in the current study preferred to line up on the "*attacking line*" (team in possession of the ball) when a ruck was formed this preferred position was also associated with a high error rate by the referees for both not dangerous and dangerous illegal ruck cleanouts and these findings were statistically significant.

The study further explored the possible reason for that influence the on-field referee's ability to sanctioned illegal (both not dangerous and dangerous). When looking at the unsanctioned not dangerous ruck cleanouts the results indicated that 83.0% (2 229) there "*no obstruction*" (referee is in position and no player is obstructing the view of the ruck), which was statistically significant (p=0.01). When exploring the dangerous ruck cleanouts, the same trend was evident with "*no obstruction*" 64.0% (f=145) being statistically significant (p=0.04). Player obstruction, referee obstruction and referee on offside line did not reveal any significant differences.

5.4. Discussion

The major findings of this study was that the on-field referee did not sanction 95.2% (f=2 548) of illegal not dangerous and 5.0% (f=217) of illegal dangerous cleanouts according to the 2020 WR Laws of the game and Kraak's *et al*. (2019) definition for a dangerous cleanout. This shows us that the on-field referee is not applying the Laws of the Game accurately and is missing a number of illegal and dangerous cleanouts. The on-field referee also sanctioned the defending team more, even though they committed less infringements. The defending team was sanctioned 28.7% (f=89) for illegal not dangerous ruck cleanouts and 7.1% (f=3) for illegal dangerous ruck cleanouts, compared with the attacking team that was only sanctioned 1.7% (f=39) for illegal not dangerous and 4.3% (f=8) for illegal dangerous ruck cleanouts. The referees arrived early at majority of the rucks but still had a high error rate for illegal not dangerous (f= 2 243; 94.9%) and illegal dangerous ruck (f=194; 95.1%). A further major finding was that the referee was in a good position when arriving at the ruck and had clear sight of the cleanout, but still had a high error rate. When

sanctioning an infringement, the on-field referee would sanction these correctly, but because of many other infringements not getting sanctioned there was a high rate not correctly sanctioned.

The findings from the current study were compared with the findings from the study conducted by Mitchell and Tierney (2020) and Kraak *et al*. (2019). Mitchell and Tierney (2020) revealed that the on-field referee did not sanction 79.9% of illegal infringements during the knockout stage of the 2019 Rugby World Cup. The above-mentioned article investigated professional rugby and it does not categorise illegal cleanouts into illegal and dangerous compared to the current study that breaks illegal cleanouts into illegal and dangerous. Kraak and co-workers (2019) found 9.0% of the cleanouts were illegal, of which 93.0% was not sanctioned by the on-field referee during the 2018 Super Rugby tournament. The difference between the studies, Mitchell and Tierney (2020) and Kraak *et al*. (2019), was that they investigated professional rugby compared with the current study that investigated school level rugby. There was one more study conducted by Brown *et al*. (2018) that investigated the sanctioning rate of the referee during the tackle and not the ruck cleanout. Brown *et al*. (2018) revealed that during the tackle the on-field referee did not sanction 59.0% of illegal actions that were not sanctioned. The referees for the tournament are appointed based on their performance prior to the tournament as well as their potential to referee at a higher level. These referees are included from the contender (developmental programme) and national panel referees (Kraak *et al*., 2011; Lawrence, 2016). When looking at the referee sanctioning rate across time it is evident that from 2015 to 2016 an increase in sanctioned illegal dangerous ruck cleanouts occurred. A possible reason for this increase could the new law changes that took place around the ruck area between 2015 – 2018. However, the high error rate by the referees in 2017 should be a major concern for rugby referee stakeholders.

The current study found that referees were not consistent with the application of the laws for the attacking and defending team because the referees favoured the attacking team more. This study exposed a trend that the defending team is sanctioned more for illegal not dangerous and dangerous cleanouts when compared with the attacking team. There were no factors that influenced this because the referee's position did not affect this and the on-field referee could see the majority of cleanouts clearly. PI's that the researchers decided upon would have a role in what influences the on-field referees sanctioning rate was: arrival time (early/late), their positioning on

the field (behind the ruck, close to the ruck, 45 degrees close at the ruck, 45 degrees far at the ruck), their position line (attacking line, defensive line), and obstructions (no obstruction, players obstructing view, position obstructing, focus on offside line). This study showed that these indicators did not play a big role as majority of the time the referee was in a good position on the field, close to the ruck where he/she had clear sight of the infringement, but did not sanction this, they rather allowed for continuity. This behaviour needs to be corrected and the on-field referee needs to abide by the Laws of The Game and accurately sanction these infringements to promote player welfare and prevent injuries. Therefore, the main reason for an on-field referee favouring the attacking team is to allow continuity of the game and maintain possession of the ball. This is in agreement with Kraak *et al*. (2017), Kraak *et al*. (2019) and Mitchell and Tierney (2020), where these studies found that the on-field referee favoured the attacking team and penalised the defending team more in order to maintain continuity of the game instead of changing of possessions and the need for set pieces (Kraak *et al*., 2016). Possible reasons for non-sanctioning by the on-field referee is because of favouring the attacking team to allow for continuity, high intensity of the game, physical fitness levels, experience, crowd, players reactions, pressure and their decision-making ability (Kraak *et al*., 2019). The ruck event is dynamic and complex with a lot of players involved, which could influence the on-field referees' accuracy (Spitz *et al*., 2016), and therefore, makes it very difficult for one referee to sanction all the infringements (Kraak *et al*., 2019). Fatigue can also play a big role in the accuracy because it decreases attention performance, and thereby, affect decision-making ability, resulting in inaccurate decisions (Rattray *et al*., 2015). Macarenhas *et al*. (2005), investigated rugby referees and concluded that they were 50% accurate with their sanctioning compared to other sports, which could be because of structure around the breakdown. The referees in the Craven Week Tournament are up and coming referees that use this tournament to improve their refereeing and their status (Boucher, 2017). These referees are chosen based on their performance prior to this tournament and their potential for refereeing at higher levels. With this being said, these referees are under a lot of pressure to perform, which could affect their sanctioning rate because of the inability to cope with this added pressure. The ability to cope effectively with the psychological demands of the game is a key determinant of successful rugby union refereeing (Mascarenhas *et al*., 2004). Training needs to be implemented for referees to assist with coping with psychological demands on field, as well as assist with the decision-making process in order to increase accuracy of decision-making in the field. The television match

official (TMO) can assist with the decision-making of the on-field referee (Pearcy, 2020), and should be given more power to intervene where necessary. A disadvantage with using the TMO to assist reducing the number of illegal actions is that it could slow the game down, which takes away the fast-paced dynamics of the game, but at the same time could help reduce the risk for injury. Simplifying the breakdown laws to cater for the dynamics of modern-day rugby, which could be implemented by limiting the number of players that can engage in a ruck (Mitchell & Tierney, 2020).

The main types of illegal not dangerous and illegal dangerous cleanouts not sanctioned by the on-field referee in this current study were: "*not supporting own body weight*" and "*neck roll*". This is agreement with the findings of Kraak *et al*. 2019. In study by Mitchell & Tierney, 2020 hips below shoulders was technique utilised the most by the players, however one should note that only 8 matches were coded in that study. It is important to note that the non-sanctioning of these infringements need to be minimised through enforcing the laws of the game more strictly and by focusing on these two illegalities that occurred the most. A big focus should be placed on the "*neck roll*" to minimize the frequency, because it has a great potential to cause a serious injury. It is of importance to minimise all contact around the head/neck during tackles and ruck events because schoolboys are more susceptible to sustain a concussion and/or catastrophic injury (Buzzini & Guskiewicz, 2006), which could result in chronic pain and disability in adulthood (Emery *et al*., 2015). Failure to penalise infringements correctly at schoolboy level increases the risk of players continuing to perform the same incorrect and unsafe techniques into senior levels, where injury risk has already increased. (Haseler *et al*., 2010). By sanctioning illegal and dangerous actions could cause an improvement in player behaviour during match-play, resulting in a decrease in the number of infringements (Mitchell & Tierney, 2020). More programmes need to be aimed at bettering on-field referees. Strict enforcement by the referees of the laws of the game will make the game safer for all involved. If the on-field referees are not enforcing the laws and prevention strategies then it will result in the prevention programmes effectiveness being reduced (Boucher, 2017). Video-based performance analysis can also be a very useful tool for the referees to self-reflect. After every match the referee can watch the match and critically review their performance, their accuracy, which will be beneficial and will show the key points and actions in a game that they need to focus on.

It, therefore, seems clear that referees, coaches and players play an integral part in cleaning up the ruck area and so additional strategies aimed at these stakeholders might be beneficial to further reduce the risk of injury at this phase of play. This perspective is also consistent with the BokSmart's adopted goal of "Vision Zero" which try to eliminate all serious injuries from the game (Brown *et al*., 2017).

Practical application

- Referees, coaches and players have a role to play in cleaning up the ruck area. The responsibility cannot be solely on the placed on the referee.
- Referees should be invited to contact training to officiate the ruck area and assist with player behaviour during training.
- Regular discussions should take place between referees, coaches and players to clean up the ruck area. This will provide an opportunity to get difference perspectives.
- Referee stakeholders and referees should develop a decision-making intervention to minimize the non-sanctioning rate. This program should also form part of referee education, which will improve the accuracy of decision-making during matches.

Study limitations

- The referee was "not in frame" during some of the rucks because of the camera angle focusing on the ruck, therefore, you could not see the positioning of the referee.

5.5. Conclusion

This study provides referees with an understanding of the importance of the decision-making process, especially at the ruck cleanout. This study highlights the high non sanctioning rate of illegal cleanouts during the 2015 to 2019 Craven Week Rugby Tournament that need to be improved. The improvement of the high sanctioning rate will lead to an improvement in player behaviour on the field and decrease the risk for injury during this event. The referees did sanction the majority of the infringements correctly, but still did not sanction a lot of infringements, which could lead to serious injury. Referees need to be stricter during contact events and enforce the laws according to the 2020 WR Laws of the Game, which should also be enforced during training sessions. This study provides important information on what a referee should be focusing on during

the ruck cleanouts and what techniques need to be focused on and sanctioned. Because of limited research on this topic at school level, it allows for more research to be conducted in order to improve the game and provide safety for all players involved.

5.6. Acknowledgement

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CHAPTER SIX

SUMMARY, CONCLUSIONS, LIMITATIONS, AND FUTURE RESEARCH

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

SUMMARY

No literature exists on the execution of legal and illegal (including both not dangerous and dangerous) ruck cleanouts and how they are sanctioned at school rugby level in South Africa (SA). Therefore, the current study sought to add knowledge not only to rugby nationally, but also internationally in an attempt to decrease the gap in the literature regarding player and referee behaviour at ruck cleanouts.

The thesis is presented in five main sections, namely: Introduction (Chapter One); Theoretical background (Chapter Two); Methodology (Chapter Three); Research Article One (Chapter Four); Research Article Two (Chapter Five); and Summary, conclusion, limitations and future research (Chapter Six). The Senate of Stellenbosch University approved the article format and the research articles are presented in accordance with the guidelines outlined by the respective journal. Currently, the Faculty of Medicine and Health Sciences at Stellenbosch University stipulates one article as a requirement for an article format Master of Science thesis.

Chapter One introduces the problem, primary aims and the objectives and hypotheses of this study.

Chapter Two (Theoretical background) describes rugby union, the ruck cleanout and behaviour towards injury prevention. From this chapter it was evident that there was limited research conducted on ruck cleanouts and that it causes the second highest number of injuries after the tackle. Investigating player and referee behaviour at ruck cleanouts, could help identify specific techniques that need improvement and assist with developing and improving current injury prevention programmes.

Chapter Three describes the methodology. This chapter explains the research design, approach to the problem, sample, data collection procedures, ethical considerations and interpretation of the findings.

Research Article One (Chapter Four): *An investigation into legal and illegal ruck cleanouts during elite youth rugby tournaments*

The article in question revealed a total of 35 545 ruck cleanouts where 91.8% were deemed legal and 8.2% illegal (including both not dangerous and dangerous). Of the 8.2% illegal ruck

cleanouts, 7.5% were deemed not dangerous compared to 0.6% dangerous ruck cleanouts. Attacking teams were responsible for executing more illegal not dangerous (88.4%) and dangerous (34.3%) ruck cleanouts. The majority of the illegal not dangerous cleanouts were "*not supporting own body weight*" (f=2 498; 99.4%), which was significantly (p=0.01) greater compared to other types of illegal not dangerous ruck cleanouts. The majority of illegal dangerous cleanouts were "*neck roll*" (f=147; 100.0%), which was significantly (p=0.02) greater than other illegal dangerous ruck cleanouts. This study also revealed that there was an increase (7.0 to 21.0%) in illegal not dangerous ruck cleanouts, which demonstrates that player behaviour deteriorated during the 2018 and 2019 rugby seasons. This increase in illegal ruck cleanouts was especially evident when the attacking team executed the following cleanout techniques: "*clearing*"; "*clearing and protecting*"; and "*protecting and clearing*". The defending cleaner techniques included: "*early counter ruck*"; and "*late counter ruck*". The above-mentioned statistics are a concern from an injury prevention perspective because illegal not dangerous and dangerous ruck cleanouts pose a major injury risk. The results from the current study highlights many areas for potential research, which could be used to improve player behaviour from a technical an injury prevention perspective. The findings from this study could assist players, coaches and all rugby stakeholders involved to understand decision-making and player behaviour during ruck cleanouts.

Research Article Two (Chapter Five): *Sanctioning of illegal ruck cleanouts by on-field referees during elite youth rugby union tournaments*

This article revealed that on-field referees only sanctioned 4.8% (f=139) of all illegal (both not dangerous and dangerous) ruck cleanouts compared to 95.2% (f=2 765) that were not sanctioned. The attacking teams was responsible for more illegal infringements compared to the defending teams, however, defending teams were sanctioned more. Attacking teams made 2 362 illegal cleanouts and only 1.7% (f=39) were sanctioned and 98.4% (f=2 327) were not sanctioned by on-field referees. Defending teams made 314 illegal cleanouts, nonetheless 28.7% (f=89) were sanctioned and 71.3% (f=221) not sanctioned by on-field referees, indicating that attacking teams were favoured. Player activities implemented by attacking teams that were significantly sanctioned and not sanctioned the most was "*clearing*" and "*protecting*" (p=0.03; p=0.04, respectively) and the "*jackal*" (p=0.03; p=0.04, respectively) by defending teams. Referees abiding to the Laws of

The Game will make the game safer for all involved. The results from the current study could assist with cleaning up rucks by focusing on certain techniques that will make this event safer.

In summary, limited research was published on ruck cleanouts across all rugby levels. Furthermore, no research investigating player and referee behaviour at ruck cleanouts and coach's role in injury prevention could be found. It is important to understand and improve both player and referee behaviour in an attempt to reduce the number of injuries during contact events, which could assist in preventing chronic injuries later on. Players, referees, coaches and rugby stake holders could all benefit from data presented in the current study.

CONCLUSIONS

The conclusions of this study are presented according to the specific objectives and hypothesis stated in Chapter One.

Research Article One (Chapter Four): *An investigation into legal and illegal ruck cleanouts during elite youth rugby tournaments*

The major findings from this study were that most ruck cleanouts were legal (f=32 641; 91.8%) compared to illegal (f=2 904; 8.2%). Regarding the illegal ruck cleanouts, 7.5% (f=2 676) were deemed not dangerous and 0.6% (f=228) were deemed dangerous. Most illegal not dangerous ruck cleanouts found in this study were "*not supporting own body weight*" compared to illegal dangerous ruck cleanouts that were "*neck roll*". The study conducted by Kraak *et al*. (2019), revealed that 9.0% (f=2 111) ruck cleanouts were deemed illegal with 5.0% regarded as dangerous, with most illegal ruck cleanouts being "*not supporting own body weight*" during the 2018 Super Rugby tournament. The study conducted by Mitchell and Tierney (2020) also investigated the breakdown and found that 37.9% of all breakdown events contained at least one illegal infringement, however, a similar trend was not found with the type of illegal cleanouts. Of the illegal ruck cleanouts found in the current study most of them were executed by attacking teams, with 92.7% regarded not dangerous and 0.7% as dangerous. This is in agreement with other studies that also found that attacking teams executed most of the illegal infringements (Kraak *et al*., 2019; Mitchell & Tierney, 2020).

The ruck cleanout techniques executed the most by attacking teams were: "*protection*", which revealed significant results (p=0.02) for legal ruck cleanouts; and "*clearing and protecting*" for illegal ruck cleanouts both dangerous and not dangerous, which was significant (p=0.04). Defending team ruck cleanouts techniques executed the most were: the "*jackal*", which was executed significantly (p≤0.00) more for legal cleanouts; and the "*early counter ruck*" technique, which was responsible for significantly (p=0.02) more illegal dangerous ruck cleanouts. The study conducted by Wheeler *et al*. (2013), found a similar trend regarding the "*jackal*" and "*early counter ruck*" defending techniques, which occurred the most during the 2011 Super Rugby tournament. It is important to remind players to 'maintain awareness' when engaging defensively at ruck cleanouts because these players are more susceptible to concussive impacts during the ruck (Hendricks *et al*., 2016).

Player behaviour can be viewed as the rate of illegal ruck cleanouts compared to all ruck cleanouts. The current study was revealed that there was an increase from 7.0 to 21.0% illegal ruck cleanouts during the 2018 and 2019 rugby seasons, which indicate that player behaviour deteriorated over this season. No research could be found to compare this player behaviour to besides the article conducted by Brown *et al*. (2018), which investigated tackles and not ruck cleanouts. Brown and co-workers (2018) found that player behaviour for tackles improved between 2011 and 2015 in the under 18 Craven Week Tournaments. The current study highlights important information on player behaviour which needs be addressed and could assist guide technique training and injury prevention programmes.

Hypotheses

H^1: It is predicted that there will be more legal than illegal (both no dangerous and dangerous) ruck cleanouts and that more illegal ruck cleanouts will occur in match periods 2 and 4 and in zones B and C.

Reject: There were more legal (f=32 641) than illegal (f =2 904) ruck cleanouts. The results did not reveal any statistical difference between the match periods and zones.

H^1: It is predicted that there will be more illegal not dangerous ruck cleanouts than illegal dangerous ruck cleanouts and that more dangerous ruck cleanouts will occur in match time periods 2 and 4 and in zones B and C.

Reject: There were more illegal not dangerous (f=2 676) ruck cleanouts compared with illegal dangerous (f=228) ruck cleanouts. The results did not reveal any statistical difference between the match periods and zones.

H^1: This study expected to reveal different types of illegal not dangerous ruck cleanouts including: neck roll; not supporting own body weight; joining the ruck while in an offside position; shoulder charge; side entry; not grasping onto teammate when cleaning; cleaning player not involved in ruck; and contact above oppositions shoulder. Shoulder charge is expected to occur the most and particularly during match periods 2 and 4 and in zones B and C.

Reject: This study revealed the above-mentioned illegal not dangerous ruck cleanouts but not supporting own body weight (f=2 498; 99.4%) was significantly (p=0.01) greater than other illegal not dangerous ruck cleanouts. There was no statistical difference between the match periods and zones.

H^1: This is expected to reveal different types of illegal dangerous ruck cleanouts including: neck roll; not grasping player; shoulder charge; not supporting own body weight; cleaning player not involved in ruck; and contact above oppositions shoulder. Shoulder charge was expected to occur the most and particularly during match periods 2 and 4 and in zones B and C.

Reject: The current study did reveal the above-mentioned types of illegal dangerous ruck cleanouts, with the neck roll occurring the most (f=147; 5.1%), which was significantly (p=0.02) greater than other illegal dangerous ruck cleanouts. There was no statistical difference between the match periods and zones.

Research Article Two (Chapter Five): *Sanctioning of illegal ruck cleanouts by on-field referees during elite youth rugby union tournaments*

The major findings from this article were that out of 2 904 illegal (both not dangerous and dangerous), ruck cleanouts only 4.8% (f=139) were sanctioned and 95.2% (f=2 765) were not sanctioned by on-field referees. There were only two studies conducted on the sanctioning at ruck cleanouts. The first study was conducted by Mitchell and Tierney (2020) at the knockout stage of the 2019 Rugby World Cup where they found that on-field referees did not sanction 79.9% of all

illegal infringements. It is important to note that the above-mentioned article only investigated 8 matches. The second study conducted by Kraak *et al*. (2019) found that on-field referees did not sanction 93.0% of all the illegal ruck cleanouts and only sanctioned 7.0% during the 2018 Super Rugby Competition. There was one more study that investigated the sanctioning rate, but this was conducted on tackles. It was concluded that during the under 18 South African Rugby Union Tournament, the on-field referees did not sanction 59.0% of all illegal tackles (Brown *et al*., 2018).

On-field referees favoured the attacking teams more by sanctioning the defending teams more often even though the attacking teams was responsible for making more illegal infringements. This finding is in agreement with the studies conducted by Mitchel and Tierney (2020) and Kraak *et al*. (2019), who also found that on-field referees favoured attacking teams more to allow for continuity in the game.

Referee behaviour can be viewed as the percentage of sanctioned and not sanctioned illegal (both not dangerous and dangerous) ruck cleanouts as a percentage of all illegal ruck cleanouts. The current study revealed that there was a significant increase ($p=0.03$) from 2015 to 2016 and a significant decrease ($p=0.02$) from 2016 to 2017 regarding illegal ruck cleanouts that were sanctioned. Regarding illegal ruck cleanouts that were not sanctioned there was a significant decrease ($p=0.02$) from 2016 to 2017 and a significant increase ($p=0.04$) from 2017 to 2018. No research could be found to compare referee behaviour besides the study conducted by Brown *et al*. (2018), which investigated tackles and not ruck cleanouts, as well as the study conducted by Mitchell and Tierney (2020) and Kraak *et al*. (2019), who investigated the sanctioning of ruck cleanouts.

Referees need to abide by the Laws of The Game and apply them strictly, which will cause a shift in player behaviour and reduce the number of illegal ruck cleanouts. Referees need to follow a zero-tolerance approach to all illegal infringements, which will lead to a reduction in the injury risk for players (Gianotti *et al*., 2009; Viljoen & Patricios, 2012; Roberts *et al*., 2015).

Hypotheses

H^1: It was predicted that 90.0% of illegal not dangerous ruck cleanouts will not be sanctioned by on-field referees, particularly during match periods 2 and 4 and in zones B and C.

Reject: This study revealed that 95.0% of illegal ruck cleanouts were not sanctioned by on-field referees. There was a significant reduction (p=0.03) from match period 1 to 2 for the illegal ruck cleanouts that were not sanctioned, but no significant difference for match period 4.

H^1: It was predicted that of the different illegal not dangerous ruck cleanouts not sanctioned, 80% would be a shoulder charge and will mostly occur during match-time periods 2 and 4 and in zones B and C.

Reject: This study found that 100.0% (f=18) shoulder chargers were not sanctioned by on-field referees. Most of the illegal not dangerous cleanouts not sanctioned were not supporting own body weight (f=2 416; 96.7%). There was no statistical difference between the match periods and zones.

H^1: It was predicted that 50.0% of illegal dangerous ruck cleanouts will be not sanctioned by on-field referees, particularly during match periods 2 and 4 and in zones B and C.

Reject: This study found that 95.0% (f=217) of illegal dangerous ruck cleanouts were not sanctioned by on-field referees, with no statistical difference between the match periods and zones.

H^1: It was predicted that of the different illegal dangerous ruck cleanouts not sanctioned, 85.0% will be a shoulder charge and 80.0% will be a neck roll.
Reject: This study found that the shoulder charge was not sanctioned 93.3% (f=28), as well as the neck roll 95.2% (f=140), with no statistical difference between the match periods and zones.

LIMITATIONS

Certain limitations regarding this study can be highlighted:

- ✓ The current study focused on the PI's surrounding ruck cleanouts at the under 18 provincial schoolboy South African Craven Week Tournament. The findings may, therefore, not be applicable to other school tournaments. It would, therefore be wise to analyse other school rugby tournaments to investigate their ruck cleanouts characteristics because they may provide a better understanding of school rugby in other countries, in both the northern and southern hemispheres.

- ✓ Weather conditions hampered the video footage.
- ✓ Angles/vague footage at times was a limitation in the sense that it was difficult to see the players' actions during a ruck cleanout.

FUTURE RESEARCH

The results from this study emphasize the importance of further research into the execution of illegal (both not dangerous and dangerous) ruck cleanouts and the sanctioning and non-sanctioning by on-field referees. Future studies should focus on the other school rugby tournaments in South Africa and other countries, as well as international elite club, and community rugby. Studies should also investigate ruck cleanout characteristics of different positions across the men's and women game. Future research on ruck cleanouts could lead to improvements in training regimes, safety and education programmes for rugby stakeholders, referees, players and coaches. Through preparing and educating players, as well as the referees regarding specific demands, in terms of the number of cleanouts per time period and the number of cleaners per ruck, could improve behaviour on the field. Studies should also focus on analysing the sanctioning of ruck cleanouts in the English, European and New Zealand school competitions to determine whether there are differences between the different countries.

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APPENDIX A

ETHICAL CLEARANCE LETTER

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PROJECT EXEMPT FROM ETHICS CLEARANCE

23 September 2019

Project number: REC-2019-10416

Project title: Incidents and sanctioning of illegal and dangerous ruck cleanouts during the 2016-2020 under 18 Craven Week rugby tournament

Dear Miss Stephanie Kruger

Co-investigators:

Your application received on 29/07/2019 15:51 was reviewed by the REC: Humanities.

You have confirmed in the proposal submitted for review that your project does not involve the participation of human participants or the use of their data. You also confirmed that you will collect data that is freely accessible in the public domain only.

The project is, therefore, exempt from ethics review and clearance. You may commence with research as set out in the submission to the Research Ethics Committee: Humanities.

If the research deviates from the application submitted for REC clearance, especially if there is an intention to involve human participants and/or the collection of data not in the public domain, the researcher must notify the DESC/FESC and REC of these changes well before data collection commences. In certain circumstances, a new application may be required for the project.

Please remember to use your **project number** (REC-2019-10416) on any documents or correspondence with the REC concerning your project. Sincerely,

Clarissa Graham

REC Coordinator: Research Ethics Committee: Human Research (Humanities)

UNIVERSITEIT
STELLENBOSCH
UNIVERSITY

Protocol Deviation

30 July 2020

Principal Investigator: Miss Stephanie Kruger

Project number: 10416

Title: Incidents and sanctioning of illegal and dangerous ruck cleanouts during the 2016-2020 under 18 Craven Week rugby tournament Dear Miss Stephanie Kruger

The protocol deviation report submitted on 9 July 2020, was reviewed by the REC: Humanities Committee.

GENERAL COMMENTS:

The REC: Humanities thanks the researcher for reporting this protocol deviation. The deviation has been acknowledged and put on record.

Please remember to use your Project number (10416) on any documents or correspondence with the REC: Humanities concerning your project.

If you have any questions or need further help, please contact the REC: Humanities office at

Sincerely,

REC: Humanities Coordinator

APPENDIX B

JOURNAL OF SPORT SCIENCES

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Journal of Sports Sciences is an international, peer-reviewed journal publishing high-quality, original research. Please see the journal's Aims & Scope for information about its focus and peer-review policy.

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

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Please include a word count for your paper.

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APPENDIX C

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You can use this list to carry out a final check of your submission before you send it to the journal for review. Please check the relevant section in this Guide for Authors for more details.

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• All tables (including titles, description, footnotes)

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• Keep the use of tables, figures and graphs to a minimum.

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• Maximum number (combined) of tables and figures is 3

• Long tables should only be included as supplementary material and will be made available on-line only

• Maximum number of references is 30

• A structured abstract of less than 250 words (not included in 3000 word count) should be included with the following headings: Objectives, Design, Method, Results, and Conclusions Review articles

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• Maximum number (combined) of tables and figures is 3

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• Maximum number of references is 60

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v. Conclusion

vi. Practical Implications - 3 to 5 dot (bulleted) points summarising the practical findings derived from the study to the real-world setting of sport and exercise - that can be understood by a lay audience. Avoid overly scientific terms and abbreviations. Dot points should not include recommendations for further research.

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Conclusions

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26 February 2021

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I, Prof Karel J. van Deventer, hereby declare that I conducted the language and technical editing of an MSc Master thesis titled, *Incidents and sanctioning of illegal and dangerous ruck cleanouts during the 2015 to 2019 under 18 Craven Week rugby tournaments*, authored by Me S. Kruger.

Yours sincerely

KJ van Deventer

(Emeritus Associate Professor [Retired])

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