THE USE OF FRAMEWORK ANALYSIS IN THE ALIGNMENT OF THE LAWS OF RUGBY TO SKELETAL DEVELOPMENT OF CHILDREN AND ADOLESCENTS

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DECLARATION

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ABSTRACT

Rugby, as a contact sport, has inherent risks of injury. Children and adolescents playing rugby at schoolboy level have a developing skeletal system and therefore injuries through this age of play may result in injuries to under-developed bones. This research study looked to identify whether the laws of rugby align to protect skeletal development of children and adolescents through law adaptations. Framework Analysis was used to develop a matrix which aligned the adapted laws of rugby with bone fusion ages. In future studies this can be used as a base for other areas of development and other sports. This matrix was further analysed to determine a severity rating scale and this scale identified some bones of the skull (occipital, sphenoid and zygomatic), upper limb (scapular, glenoid and clavicle) and lower limb (sacrum and pelvic girdle) as having a higher risk for severe injury. While these bones are at severe potential risk of injury it is important to note that only one measure of maturation was used and in future additional measures of maturation should be used. In conclusion, while the adapted laws of rugby do protect some bones of the developing skeletal system, they do not protect all of the developing bones of the skeletal system. The matrix could be used to guide future law makers in their endeavour of making the game of rugby safer for children and adolescents.

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Table of Contents

List of Figures

List of Tables

Abbreviations

FA	Framework Analysis
SARU	South African Rugby Union
TRIPP	Translating Research into Injury Prevention Practice framework
WR	World Rugby

Operational Definitions

Adapted rugby law	A law which has one or more adaptations to the World Rugby law for different age groups e.g. Primary School Law Variations [1]
Non-adapted rugby law	A law which has no adaptions the World Rugby law for different age groups e.g. Primary School Law Variations [2]
Injury	"Any physical complaint, which was caused by a transfer of energy that exceeded the body's ability to maintain its structural and/or functional integrity, that was sustained by a player during a rugby match or rugby training, irrespective of the need for medical attention or time-loss from rugby activities. An injury that results in a player receiving medical attention is referred to as a 'medical-attention' injury and an injury that results in a player being unable to take a full part in future rugby training or match play as a 'time-loss' injury" [3 p329]
Occupational deprivation	"A state in which a person or group of people are unable to do what is necessary and meaningful in their lives due to external restrictions" [4 p200]
Occupational disruption	'Disruption in occupational engagement due to significant life events (such as having a baby), environmental changes (such as moving house or location), becoming ill or sustaining an injury from which full recovery is expected' [4]

Overuse Injury	"Overuse injury is the result of excessive stress applied to normal tissue and failure of normal adaptation" often occurring in sport with repetitive movement such as tennis [5 p553]
Rugby Union	A contact ball sport played globally [6,7] played by two teams with 13-15 players per team where the aim of the game is to either kick the ball over the opposing team's goal line, or by passing and strategically kicking the ball, to ground the ball over the opposing team's goal line [8]

CHAPTER 1 INTRODUCTION

1.1. Introduction

The core construct underlying the practice of occupational therapy is participation in meaningful occupation. In order to understand the different occupations in which people engage and the effect the occupation and environment can have on participation the separate, academic discipline of occupational science was developed in the 1990s. Hocking [9] indicates that one of the operational areas of focus in occupational science is the relationship between an occupation and other phenomena. The research direction for this focus includes explaining how occupation relates to human development. This study therefore uses the unique perspective as outlined in the framework of occupational science knowledge and research directions to determine if the adaptation of a leisure activity, specifically rugby, accommodates skeletal development of schoolboys.

For school going children and adolescents involvement in structured team sport is seen as an important addition to their leisure interests, as the physical and emotional benefits are viewed as vital for development [10]. However, participation in such occupations should be balanced against the risk to wellbeing they may present if the benefits they provide are to be fully appreciated.

Rugby is one such team sport and is one of the most popular contact sports globally played by two teams with 15 players per team [6,11]. Rugby played at schools, both within the academic and extracurricular settings presents the potential for injury since the contact nature of the sport makes it inherently risky. An injury is defined as “Any physical complaint, which was caused by a transfer of energy that exceeded the body’s ability to maintain its structural and/or functional integrity, that was sustained by a player during a rugby match or rugby training” [3]. Freitag, Kirkwood, Scharer, Ofori-Asenso and Pollock. [8] reported that 28% of all children and adolescents playing rugby are likely to sustain an injury during a given season. Even with the inherent risk, the sport is compulsory within the curriculum of many schools [12,13] in countries such as Australia and New Zealand, providing the children with no choice as to whether they wish to play or not. Although this is not a compulsory sport in all schools in South Africa, rugby is played in many primary and high schools. Thus, competitive rugby at school level is played predominantly by males and therefore this study focuses on the skeletal development of male children and adolescents, hereon referred to as "schoolboys".

It is of therefore of concern that South Africa has a lower than expected injury rate reported in schoolboy rugby compared to other countries. This is mostly attributed to the under-reporting of injuries [6] as at school level, there appears to be no mechanism of reporting and recording of rugby-related injuries. Combined with the under-reporting of rugby injuries [14], there is a dearth of evidence on whether the current school-level laws of rugby ensure the safety of children and adolescents who play rugby. In South Africa, The South African Rugby Union (SARU) is the governing body that aims to promote safe play in rugby and has thus produced a number of law variations for the game according to the level of players schooling or age group in which they play [1]. These variations to the laws are important when considering protecting players as there is a relatively high risk of injury associated with rugby.

This research will therefore examine whether the laws of rugby protect the developing skeletal system and what the potential risk for injury to the developing skeletal system is for schoolboys playing rugby.

1.1. Statement of the problem

There is little evidence on whether the number and severity of injuries among schoolboy rugby players has increased or decreased since the adaptation of certain laws for different age groups introduced by SARU most recently in 2019 [1]. Studies that have been published on these laws are specifically related to the implementation of the Boksmart programme rather than how the laws are aligned to the players developmental level [15,16]. It is unknown if the laws implemented for the different age groups in schoolboy rugby potentially place the players at risk of injury as there is currently no research on how the laws match the skeletal development of children and adolescents. It is noted that in 2019 changes were made to adult rugby laws to only allow one man tackles and how illegal tackling is punished [17]; however, this still does not change the legal tackling in relation to age or stage of development for children and adolescents.

1.2. Purpose of the study

The purpose of this study is to determine whether children and adolescents who are playing rugby are at risk for skeletal injury. Since rugby is played at schools, both within the academic and extracurricular settings, there is a need to understand the potential risk for injury associated with participation. This review of the laws of the occupation of rugby at school-boy level will be relevant to all children and adolescents who are playing rugby, and who are at risk of sustaining an injury. This potential injury may place these children and adolescents at risk of occupational disruption [4], due to time away from other occupations such as school while recuperating.

1.3. Research question

Do schoolboy rugby laws address the potential risk to bone development of schoolboy rugby players?

1.4. Research Aim

This research aims at determining whether the analysis of the laws of schoolboy rugby in relation to schoolboys' skeletal development addresses the potential risk of playing this contact sport.

1.5. Objectives

1. To develop a matrix for the analysis of the potential risks selected laws of rugby at schoolboy level pose to bone development in schoolboys.
2. To identify the potential risk of playing rugby on the developing skeletal system of schoolboys.

1.6. Justification for the study

The results of this research will be used to create awareness for changing the laws of rugby to increase the safety of young players as well as to increase awareness of the need to understand development of children in relation to the laws of rugby. This research is necessary to provide information to parents, coaches and Provincial Rugby Unions to ensure that the school-level rugby laws match the skeletal developmental trajectory of children and adolescents. The findings of research may be useful in indicating any gaps within the laws of rugby that potentially place children and adolescents at risk of injury at each stage of their development. The results of the research project will be submitted to a peer-reviewed academic journal for publication and disseminated to the rugby regulation committees to inform their decision-making regarding the greatest safety of all the players.

This research report will introduce the reader to skeletal development, sport injuries, rugby and finally rugby injuries through a thorough the literature review. It will then describe the methodology of Framework Analysis and how this was used in the study. The results of the Framework Analysis will then be described in the results, discussed in relation to current literature in the discussion and concluded with recommendations in the conclusion.

1.7. Structure of the research report:

Chapter 1 Introduction to the study including the statement problem, purpose of the study, research question, aims and objectives and justification for the study.

Chapter 2: Literature review

Chapter 3: Methodology chapter explaining the use of Framework Analysis to answer the research aims and objectives

Chapter 4: Results of the study determined through Framework Analysis.

Chapter 5: Discussion of the results of the study seen in Chapter 3

Chapter 6: Conclusion of key findings and recommendations for future research, policy and practice.

CHAPTER 2 LITERATURE REVIEW

2.1. Introduction

This literature review considers bone development and fractures, the benefits of playing sport, the potential risk of sustaining an injury while playing sport including rugby, rugby including the laws of the sport and occupational disruption from a rugby injury.

Literature was sourced from the following databases: EPIC, EBSCOHost, PubMed, ClinicalKey, CINAHL complete and SPORTSDiscus. The search for literature covered all research from 1980 to 2019 as iconic initial research on injuries in schoolboy rugby was completed in the last part of the 20th century and the literature on laws in rugby more recently. Search terms used included, but were not limited to: Sport, Sport in children, Sport injuries, sport Injuries and children, Rugby, Rugby injuries, Rugby injuries and children, Development of bone, Fractures, Broken Bones.

2.2. Bone development and Fractures

In childhood bones grow continuously at the epiphysis, physis, metaphysis and diaphysis [18]. The epiphysis, or secondary ossification centre, produce bone until all cartilaginous areas are bone and are fused [18]. While developing, there is an imbalance between the weaker developing bone and the functionally stronger ligaments and tendons [19,20]. This imbalance places the bone at an increased risk for fractures from forces which would normally cause a strain or sprain in an adult [21]. This risk for fracture is of most concern when it is near the physes or growth plates in children; a fracture which includes the physes can have long lasting complications including disruptions in bone length, bone fusion and deformities [18].

It is important therefore, to understand the factors influencing bone development and the impact injury has on it. The imbalance between bone strength and ligament and tendon strength is consistent with the types of sport injuries seen in children [21,22]. This risk for fracture decreases as the bone fuses and strengthens in relation to the ligaments and tendons surrounding it [23]. Children, therefore, are most at risk for fractures (both overuse and traumatic) ranging from complete fractures to greenstick fractures [23].The risk for ligament, tendon and muscular injuries, however increases during this stage and is especially common in adolescents. This increase in injuries is seen in many sports including rugby both internationally and locally [8,24,25].

The risk of sustaining a fracture has a high impact on the developing skeletal system. Even though childhood fractures generally heal without complications, fractures associated with growth plates place the developing skeletal system at risk for asymmetrical growth, or the formation of spurs if they do not heal correctly [18,26]. Thus, the risk of skeletal injuries, particularly those which occur in sport, need to be considered against of the benefits of sport.

2.3. Benefits of playing sport

The benefits of playing sport are widely recognised both internationally and locally and research which addresses this ranges from specific studies with various measures to systematic reviews [27]. The benefits on which the literature agree include decreased body fat percentages and obesity [28], improved social interactions [29], and decreased behavioural problems in adolescence [30]. Other benefits included improved mental health, self-esteem and body image [31]. Many studies suggest that there is a positive correlation between playing sport and improved health [32–34] however playing sport, especially contact sport, does also come with the potential risk of injury.

2.4. Risks of injuries when playing sport

The term injury, in literature, does not have a standard definition, which affects the reporting of injuries sustained while playing sport and subsequently the statistics available on the incidence of sport injuries, especially in children and adolescents [3]. Patel and Baker [5] indicate that most definitions of sport injury have at least one of the following criteria: the need for medical attention, time lost from play (practice or game) or some form of decrease in level of activities. Although the definition of injury is not consistent, what is consistent is the large number of people engaging in sport who sustain an injury and the need to better understand these injuries. Injuries from sport range from minor injuries with no time loss in play, to severe injuries which can result in disqualification from an activity for a greater length of time [8]

Sport injuries are distributed amongst both solo and team sport, however, the type of injury, severity of injury and cause of injury may differ based on type of sport, gender, level of participation and position played [21]. In the last 10 years, the amount of literature on sport injuries in children and adolescents has increased significantly [35–39], which is indicative of the necessity to better understand the types of injury, the sport that causes the most injuries and what is needed to reduce these injuries in children and adolescents.

2.4.1. Prevalence of sport injury in children and adolescents

Internationally, an increase in sport-related injuries have been reported [40], however, there is no agreement on the exact factors which predispose children and adolescents playing sport to injuries. Developmentally, two proposed factors which may increase the risk of sport injuries include: the move from free play to organised, competitive play, and the physiological changes which occur in growing athletes [26]. These two factors are considered to contribute to the statistics indicating that injuries range from 1 in 10 children to 1 in 3 children [41]. In the United States of America it is estimated that 2 million high school sport injuries occur each year with 30,000 of those injuries requiring hospitalisation, but these figures exclude children under the age of 13 [42].

Patel, Yamasaki and Brown [43] report the sport responsible for the highest rate of injury in adolescents is American Football which is a contact sport, followed by boys' soccer, girls' soccer, boys' volleyball, girls' volleyball, boys' basketball, girls' basketball, boys' wrestling, boys' baseball and finally girls' softball. Rugby was not included in their study, but as a contact sport may be aligned with American football. Dangelmajer, Grant, Pan, Ho, Kintzing and Connolly [44] in their study of contact sports (which included ice hockey, rugby, martial arts, and boxing), also found a high incidence of injury. Other studies have reported similar findings [39,44–46]. Most of the literature on injuries in children and adolescents in contact sport reports on American football injuries with a difference in injuries for junior and senior students playing American football, even though the game is played in the same manner. This indicates age and skeletal and other developmental factors may predispose these players to different types/patterns of injuries.

2.4.2. Types of sport injuries

The most common type of sport related injuries also seen in contact sports are contusions, strains and sprains, extremity fractures, concussion and less commonly ligament and muscular injuries [21,22,46].

Sport injuries can be divided into traumatic or overuse injuries, both of which are important considerations. Overuse injuries is described as an injury to a part of the body due to fatigue caused by repetitive movements [47]. These injuries often result in longer term loss of playing time compared to acute injuries [20]. Numerous papers are available describing overuse injuries [19,46–50] and although these injuries have implications for the developing musculoskeletal system [47,49,50], they are not as common in contact sport and not as commonly described in literature as traumatic injuries for sport such as football, rugby, ice hockey and soccer.

Traumatic injuries are described as an injury sustained from a specific event [41] and for this literature review, traumatic injuries will be used as the descriptor for sport injuries rather than overuse injuries although overuse injuries should be considered for rugby players in future studies.

2.4.3. Risk of injury in contact sport to schoolboys

As children grow and mature, the types and patterns of injuries also change, therefore the most common injuries are likely to be different for children and adolescents.

The probability of an older schoolboy sustaining an injury (musculoskeletal etc.) while playing contact sports is high, but the risk and type of sport injuries seen in older adolescents may be more similar to those seen in adults [51]. This is important, since it is understood that as adolescents develop they are more likely to present with adult-like injuries rather than child-like injuries and predispose themselves to further skeletal damage which may lead to injuries as adult players [26]. In adolescents, due to the pace of the game being faster, the size of the players being greater and the force with which they connect to each other being larger, more contusions and concussions are seen than in younger players [52].

Traumatic injuries in the teenage years do include fractures, but these are more likely to be midclavicular fractures, humeral shaft fractures and dislocations of the glenohumeral joints [20]. Lynch, Kemper, Turi-Lynch, Agostinete, Ito, Luiz-De-Marco, Rodrigues-Junior and Fernandes[53] showed slightly lower probability of adolescents sustaining any bone injury (21%) while playing sport in general. These findings are consistent in contact sport such as American football making it an important consideration for ensuring the laws of the sport protect against injury based on the physical development of the players [54]. For this study only injuries sustained while playing rugby should be considered.

2.5. Rugby

Rugby, the third most popular contact team sport [55], is played by approximately 204,119 male and females of varying ages in South Africa [8]. Rugby is a sport played by two teams with 13-15 players on a side where the aim of the game is to either kick the ball over the opposing team's goal line, or by passing and strategically kicking the ball, to ground the ball over the opposing team's goal line [8]. This sport is played competitively in many South African schools with multiple school, district and provincial festivals such as the Craven Week and Academy Week. It is one of the fastest growing sports internationally and approximately five million people play rugby in over 117 countries [6]. With so many people participating in the sport a well-coordinated and controlled set of regulatory boards are in place in countries where rugby is played.

2.5.1. Organisation of Rugby governing bodies

This section of the literature review will describe these control boards and their role in protecting players the game of Rugby. Regulatory bodies in Rugby follow a top down organogram, as illustrated in Figure 2.1.

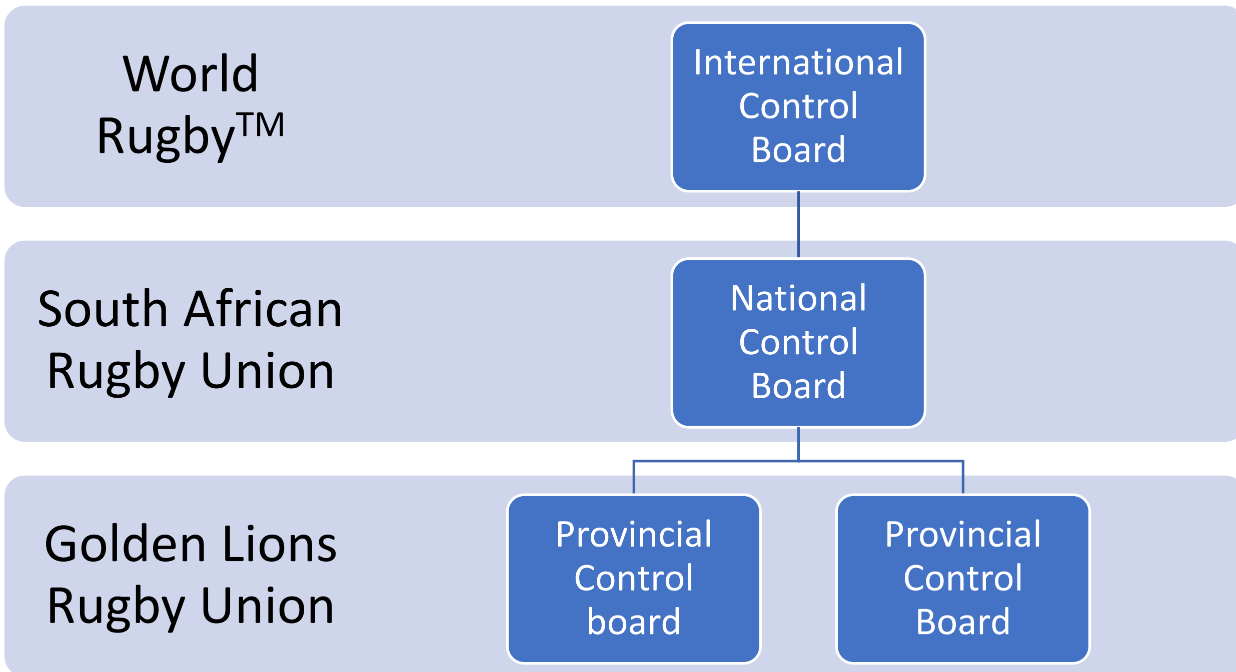

Figure 2.1: Organogram of rugby organisational structure

Regulatory bodies in rugby follow a top down organogram, as illustrated in Figure 2.1. The International control board or World Rugby™ governs all the laws for Rugby. This control board was developed in 1886 in Dublin, Ireland and is the governing and law-making body for rugby [56]. It was referred to as the International Rugby Board until November 2014 at which stage the name was changed to World Rugby as a rebranding of a rapidly growing organisation [57]. All countries that play rugby belong to the World Rugby Organisation as the international law governor and developer, however each country has a local governing body for the sport. In South Africa, the local body for governing rugby is the South African Rugby Union (SARU).

The SARU aims to promote safe play for all rugby players. To increase the safety of the game in the South African setting, SARU has produced a number of law variations for players according to their level of schooling or age group in which they play. These variations to the laws are important when considering the safety of play as there is a high risk of injury associated with rugby [58]. For schoolboys engaging in the game it is important to have an idea of the risk associated with the game, and the phases of play most associated with injuries so the laws may be appropriately adapted to increase the safety of the game.

2.5.2. Laws of rugby

There are 21 laws of rugby with multiple sub-laws within each law to regulate how the game is played [2]. These laws have variations for different levels of school e.g. Primary School [1] or for different age groups such as the scrum law for ages under 7 to under 10 year old [2]. In the case of scrummage, the laws were adapted to increase the safety of the game, but very little literature is produced describing how the laws of rugby are adapted and whether they increase or decrease potential risk for injury [59]. There are adapted and non-adapted laws of rugby which need to be understood according to the developing skeletal system.

2.5.2.1 Non-Adapted laws of rugby

Of the 21 rugby laws which are described in the Laws of rugby [2] there are a number of laws that were adapted for school children. This section will describe both the adapted and non-adapted laws. The non-adapted laws and their potential for injury are presented in Table 2.1.

Table 2.1: Laws of rugby with no adaptations for school level rugby

Law		Description	Potential risk
6	Match officials	Number, appointment and duties of the different officials for a game	None
7	Advantage	The benefit a team gains when the opposing team has an infringement. Includes when advantages being and end.	None
10	Offsides and onside in open play	Players must be in the correct area of play when engaging in play or are penalised for offsides	None
11	Knock on and throw forward	A player makes contact with the ball and the ball goes forward either intentionally or unintentionally	None
12	Kick-off and restart kicks	Used to start each half of the match or extra time or is used when a ball is dead.	None
13	Players on the ground in open play	Players are to play the game while on their feet only however may be on the floor during a tackle	None

Law		Description	Potential risk
14	Tackle	The ball carrier is held by an opposing player and brought to the ground in a safe, fair manner	High
15	Ruck	Competing for the ball which is on the ground by at least one player from each team are on their feet but in contact with each other to get the ball	None
17	Mark	A player stops the ball within their own 22 line by directly catching an opponent kick	None
20	Penalty and Free kick	A manner in which to restart play after an infringement	None
21	In-goal	The manner in which a player may score points while at the score lines either through touch or kicking through the goal posts.	None

Of the eleven non-adapted laws, ten do not pose a potential risk for injury and meet the requirements for laws of rugby which make a game safer. These eleven laws are specific to phases of play and not only protect a player from injury but also improve the management of the game [60]. An infraction relating to these laws result in a penalty and in severe instances, a player may be removed from play, either temporarily (in the case of a yellow card) or for the remainder of the match (in the case of a red card).

Of the non-adapted laws of the game only one poses a high potential risk for injury. Tackling (Law 14), which is described as the method of bringing the ball carrier to the ground [2], is an important law to understand due to the high potential risk of injury.

Tackling is the most dangerous phase of play [8,58,60–63] for both the ball carrier and the tackler, for three reasons. Firstly, it occurs frequently during the game [64], secondly, many injuries are associated with tackling [65], and thirdly, the nature of the injuries is often severe [6], resulting in occupational disruption.

Tackles are identified as the most common match event therefore if a higher proportion of the match time is spent in tackles there should be a high proportion of tackles occurring [61]. Fuller, Brooks, Cancea, Hall, and Kemp [66] described a tackle occurring 221 times per match per professional rugby player over two seasons, which is the highest collision type during a match when compared to maul, ruck, scrums etc.. Similarly, Quarrie and

Hopkins [67] reported 293 tackles per match, indicating that a significant amount of time is spent during a game on tackling.

There is no consensus on the exact percentage of injuries which occur in the tackle. Kaplan, Goodwillie, Strauss, Rosen and Beer [50] describe the risk for injury as 36-56% whereas Roux et al. [61] reports it to be as high as 48-60% of injuries. Although the study by Roux, Goedeke, Visser, Van Zyl and Noakes was completed more than 20 years ago, it should be understood that the severity of this phase of play has not decreased since 1987 but rather the ability to determine when an injury occurs may have increased with technology [68].

Tackle injuries have been described in literature in separate groupings associated with the position in the tackle. Two positions are described, namely the ball carrier (the player who is being tackled) and the tackler (the player initiating the tackle to gain possession of the ball) [25]. The need for separate groupings according to player position is that the type of injuries differs between each player. Tacklers are more likely to sustain upper body injuries such as concussions and head/neck and shoulder injuries whereas ball carriers are more likely to sustain lower limb injuries[66,67]. Burger, Lambert, Viljoen, Brown, Readhead and Hendricks[25] found that the injuries from both tackler and ball carrier were joint, tendon and ligament injuries (29%), followed by bruises and contusions (22%).

Despite tackling being a frequent occurrence and a dangerous phase of play, tackling is not adapted for primary school or high school players according to the SARU Primary School Law Variations [1]. Due to the forces involved during tackling, players therefore are at greater risk of injury due to their underdeveloped skeletal systems.

2.5.2.2. Adapted laws of rugby

The laws of rugby for schoolboys are adapted in two areas; the first areas (Table 2.2) is the adaptation of laws regarding players, officials, field and equipment. The second area (Table 2.3) is the adaptation of laws applied to play. These two tables will be discussed separately while describing their ability to protect players. Table 2.2 includes law adaptations for the ground, ball, the team, players clothing and time and include five adapted laws for schoolboys; these laws are presumably adapted to increase the safety of younger rugby players, but SARU does not make the reason for adaptations explicit. The laws chosen to be adapted, do not appear to be in line with commonly reported injuries in the literature, however, since these adapted laws have not been linked to injuries in the literature, it may indicate that they are protective in nature. This is not definitive due to the lack of literature on how laws of rugby are adapted.

Table 2.2: Adapted Laws for school level rugby– applied to players, officials, field and equipment

Law– players, officials, field and equipment		Adaptations of laws to protect players
1	Ground (The size, surface type and markings of the playing Ground)	Primary school children - reduced playing field as well as moving the dash lines and touch lines closer from 5m to 3m and 15m to 13m respectively.
2	Ball (The size, shape and weight of the Ball)	Primary school – a size 4 ball is used until age 13
3	Team (The number of players (including squad sizes), positions of the players and replacements of the Team)	Primary school – may have a maximum of 8 players being replaced during a game U13-U19 - at least 6 possible replacements allowed in a game
4	Players Clothing (The type of uniforms and additional gear allowed and not allowed to be worn)	Primary school children- all children must play barefoot. Mouthguard are recommended but are not compulsory unless playing a provincial tournament
5	Time (Amount of time for matches, rest time and injury time allowed for games	U9 to U12 - two halves of 20 minutes running time with a maximum of 5 minutes for half time and 5 minutes for injury time U13- Two halves of 25 minutes running time with a maximum of 5 minutes for half time and 5 minutes for injury time U19 - two halves of 35 minutes with no extra time permitted

Table 2.3 includes law changes for different types of play that occur during a game of rugby which are scoring, foul play, mauling, touch, quick throw and line out and scrumming.

Table 2.3: Adapted of laws for school level rugby - applied to play

Law- applied to play		Adaptations of laws to protect players
8	Scoring (Methods and points value of scoring points including Try, Penalty and Conversion points)	U9 and U10 - required kicking to convert a try is at a reduced distance (13meters) and touch line is also reduced to 13m.
9	Foul play (Action by a player which is against the laws, includes: obstruction, unfair play, repeated infringements, dangerous play and misconduct.)	Primary school: A player must not create the impression at the tackle that he is been played in the air by jumping over a player. No sling tackle (using an outward stretch arm to stop a player, most commonly above the shoulder line) is allowed, its dangerous play. Yellow Card suspensions are reduced to five (5) minutes running time.
16	Maul (Competing for the ball which is held off the ground by at least one player from each team while in the field of play.)	Primary School: A maul may only move ten (10) metres before the referee will instruct the players to play the ball. If after 5 seconds the ball does not come out a scrum will be awarded for safety.
18	Touch, quick throw and line out (Method of restarting play when a ball has gone beyond the boundaries line by either a touch, quick throw or line out)	Primary School: All seven (7) suitably trained forward players (positions 1, 3 to 8) must form the line-out but are only required to throw the ball three (3) metres rather than the five (5) metres of adults. The player catching the ball must jump and must not be lifted. He may not be tackled upon returning to the ground.
19	Scrum (A Manner in which play is restarted after stoppage or a minor infringement but the binding of two teams in a crouched position. The teams then push to get possession of the ball)	Primary School: Adaptations for scrumming range from a 3-man uncontested scrum with a maximum of 10 player to a 5-man uncontested scrum with a maximum of 15 players. High School: Full scrum formation with pre-scrum binding and a maximum of one and a half (1.5m) metre pushing.

Literature describing injuries in rugby, relate the injuries to phases of play and foul play. All injuries occurring during scoring have been attributed to foul play and not to the phase of play.

Kaplan et al. [55] described a high incidence of fractures to the head and neck predominantly due to foul play. This indicates that foul play, although adapted, still has a high precedence of injuries. Although the literature has described injuries related to foul play the number of injuries is less when compared to tackling and scrumming.

Scrumming occurs in an international rugby match for 1 minute and 16 seconds on average per match [69] which is relatively low when compared to other phases of play such as tackling. However, the severity of injuries associated with scrumming can be a lot worse. Injuries in scrumming, like tackling injuries, are often position based and positions such as the front row players are more at risk than the back row players [70]. While extensive literature is written on the safety of scrumming [58,71–75] there are mixed opinions on whether it is in fact safe or not. The impact of scrumming on injuries in schoolboys, while possibly under-estimated [71], is reported between 2.0-36.0% in a systematic review by Freitag et al. [8] whereas tackle related injuries are between 39.6-64.0%. This indicates that in children and adolescents there is a risk of injury while scrumming, but the risk of injury is not as high as tackling.

While the incidence of injuries associated with the scrum may not be as high as tackling, the injuries may be catastrophic [76]. In a scrum, two teams place an increased amount of biomechanical forces onto each other, which, when done correctly allows for a controlled force to be placed equally on all players [75]. However, if a scrum collapses (players falling onto the ball) the risk of injury increases. While there is extensive literature describing the dangers of scrumming, there is limited literature describing the types of injuries sustained from a scrum. McIntosh [58] described a small number of injuries to the spine and vertebral column as most commonly linked to scrumming. The small number of incidences may be due to the amount of education and training on scrum safety and the understanding of the risk of spinal injuries [58]. The danger of any injury, temporary or permanent, is the occupational disruption which may occur.

2.5.3. Definition of Rugby Injuries

The definition of rugby injuries have been widely discussed in literature as there is no consensus on the definition and therefore has made systematic reviews of the literature difficult [6,8]. Table 2.4 below illustrates the differences in definitions of injury from a range of cited papers in studies.

Table 2.4: Definitions of injury in studies related to rugby

Author (s)	Date	Definition of rugby injury
Fuller C, Molloy M, Bagate C, et al. [3]	2007	"Any physical complaint, which was caused by a transfer of energy that exceeded the body's ability to maintain its structural and/or functional integrity, that was sustained by a player during a rugby match or rugby training, irrespective of the need for medical attention or time-loss from rugby activities. An injury that results in a player receiving medical attention is referred to as a 'medical-attention' injury and an injury that results in a player being unable to take a full part in future rugby training or match play as a 'time-loss' injury"
McManus A, Cross D.[77]	2003	An injury while playing rugby, irrespective of the need for medical attention or time-loss from rugby activities"
Durie R, Munroe A. [78]	2000	
King D.[79]	2006	
Nathan M, Goedeke R, Noakes T [80]	1982	Medical Attention Injury: An injury that requires medical attention either at the field or by medical personnel at a secondary site.
Gabbett T.[81]	2004	
Usman J, McIntosh A.[82]	2013	
Haseler C, Carmont M, England M.[83]	2010	
Palmer-Green D, Stokes K, Fuller C, et al.[84]	2013	
McIntosh A, McCrory P, Finch C, et al.[85]	2010	Time Loss Injury: A injury that results in a player being removed from play rugby for a period of time
Collins C, Micheli L, Yard E, et al. [86]	2005-2006	

Table 2.4 illustrates the number of different definitions given for injuries in rugby literature. The reason for these discrepancies in the overall risk of rugby is due to the measurements

used as well as the vast number of definitions used for an injury, resulting in different statistics being produced in different literature. World Rugby describes an injury as either a medical injury or a time loss injury [3]. In this literature review the definition for injury as used by World Rugby will be used.

2.5.4. Injury risk for schoolboys playing rugby

Rugby presents an high risk of injury as seen in the number of rugby injuries when compared to other sport [87,88]. Due to the factors described above, differences in risk have been described with the study by Brown, Lambert, Van Mechelen, Viljoen, Hendricks, and Readhead . [89] including 1,804 players describing the risk of sustaining a rugby injury as 69 injuries per 1000 hours of exposure, whereas Freitag et al. [8] described an overall 26.7 hours per player-hours risk of injury irrespective of medical attention or time loss.

Risk has been described in relation to time of the season, age of player, level of participation as well as phase of play posing greatest risk however, there is little agreement between studies as to what should be the criteria with which to measure risk.

2.4.4.1. Time of the season

The rugby season in South Africa is most associated with winter. Roux et al. [74] determined that most injuries occur at the start of the season when players are not fit and mid-season during the winter school holidays when rugby tournaments are played. Injuries are also more likely to occur in the second half of rugby games with 33% of all injuries occurring in the third quarter [90]. The reasons for this increase in injuries is unclear and further specific research is required to explain this phenomenon.

2.4.4.2. Age of player

Age of player has been identified as a risk factor; however, the exact age of injury has not been agreed upon. Roux et al. [74] reported that significantly more injuries occur after the age of 16, whereas Brown et al. [89] found the number of injuries increased with age in their one week survey of schoolboy rugby injuries. Freitag et al. [8] determined that the probability of a rugby player sustaining an injury in a season ranged from 9% to 98% in under 9s - under 12s and under 18s respectively in a single season. These three studies, although they do not agree in the exact percentage of risk associated with an increase in age, conclude that the risk of injury increases as a players age increase.

2.4.4.4. Phase of play

Certain phases of play are more associated with injuries than others. Tackling is considered the most dangerous phase of play [8,58,60–63] for both the ball carrier and the tackler. Although there is no consensus on the exact percentage of injuries which occur in the tackle phase Kaplan et al. [55] describe the risk for injury as 36-56% whereas Roux et al. [74] report it to be as high as 48-60% of all injuries sustained.

There is no literature on injuries occurring when players score a try. Scoring is a predominantly safe phase of play, and although injuries do occur when a team is scoring, these injuries are more often due to foul play, or tackling. Most other injuries, 54% to 63% occur in the scrum, ruck or maul [89]. There is extensive literature on the safety of scrumming [58,71,73–75] with mixed opinions on the its safety. The impact of scrumming on injuries, while possibly under-estimated [70], is reported between 2.0-36.0% by Freitag et al. [8] in their systematic review. Again, while there is limited agreement between the exact percentage of injuries, it is indicated that tackles are the most dangerous phase of play.

2.4.4.5. Levels of participation

Archbold, Rankin, Webb, Nicholas, Eames, Wilson, et al. [90] found in their study that there was a significantly higher risk of injury for age and playing club or provincial rugby. Similarly, players who were playing for top tier schools, e.g. were more likely to get injured. This indicates the higher the level of participation the greater the chance of injury.

2.5.4.1 Skeletal injuries associated with rugby

Compared to concussion, there are fewer studies on musculoskeletal injuries including tears and sprains of ligaments, tendons and muscles and fractures in children and adolescents [8,60,65]. However, musculoskeletal injuries are more common than concussion.

The risk of fractures as seen in a systematic review [8] ranged from between 3% to 27% and dislocations and subluxations between 0.5% and 10.8%. Similarly, Burger et al. (2014) identified that 13% of time-loss injuries were fractures [65]. The incidence rates for fractures ranged from 0.8/1000 player-hours to 11.3/ 1000 player-hours in schoolboy rugby [74,77].

The study by Kaplan et al. [55] on adults which found that the lower limbs are the most injured region of the body is supported by Constantino and Bentley [60] although they also included the head and neck as common injury sites. Adult injuries may be important to consider as adolescents may develop similar injuries to adults rather than those of children.

Burger et al. [65] found that although the lower limb is the most commonly injured region of the body, the phase of play and the position the player assumes also affects the site and type of injury. Roux et al.[74] reported that muscle injuries and fractures are distributed across all playing positions but that 50% of injuries sustained by hookers are dislocation or fracture of the upper and lower limbs while 62% of injuries sustained by locks are also fractures or ligament injuries of the upper and lower limbs.

Kaplan et al. [55] described a high incidence of fractures to the head and neck predominantly due to foul play. Although injuries associated with foul play have been described, the number of injuries is less when compared to tackling and scrum, nonetheless it is an important factor in relation to injuries.

Notably, when upper extremity injuries occur, they are often more severe. Eighty percent (80%) of the severe injuries to the hand were fractures. Herrington, Lee, Horsley, Whitaker and Rolf [91] demonstrated that tackling adversely affected sensorimotor function in the shoulder joint with a predisposition to future traumatic shoulder joint injuries because of joint instability and repetitive microtrauma. Archbold et al. [90] report that upper limb fractures result in a median loss of 66 playing days (range 10–171) while other bone fractures result in a median of loss of 23 days, muscle injury 65 days and dislocation 58 days.

2.5.5. Prevention of rugby injuries

There is a paucity of research into rugby injury prevention. The literature describes two main approaches, namely Translating Research into Injury Prevention Practice framework (TRIPP) [92] and the rugby union specific programmes such as the RugbySmart [93] and BokSmart [16] programmes.

The TRIPP identifies six stages of injury prevention strategies (Injury surveillance, establish aetiology and mechanism of injury, Develop prevention measure, Scientific evaluation, Describe the intervention context and Evaluate the effectiveness of the prevention measure) based on the existing knowledge of the injury patterns and external factors within specific settings [94]. The focus of the TRIPP is to ensure that researchers are not only producing theoretical knowledge but continue to ensure the findings are then implemented and evaluated. The six steps suggested by Finch, Gabbe, White, Lloyd, Twomey, Donaldson et al. [95] require injury surveillance as the base and is therefore retrospective rather than predictive of injuries. Therefore, the focus on preventing injuries is based on injuries which commonly occur in the game rather than pre-emptively identifying where injuries may occur.

Another injury prevention strategy is the 'RugbySmart' programme. RugbySmart is a joint project of the Accident Compensation Corporation and the New Zealand Rugby Union to produce evidence-based information to reduce injuries in rugby since 2001 [93]. The focus of RugbySmart is to continuously provide evidence-based information to players, coaches, and policy makers within New Zealand on injury statistics and injury prevention strategies which can be implemented [93]. RugbySmart was initially used to disseminate important information on injury risk and prevention strategies which included workshops and enforcing a strict non-attendance of workshops resulted in no games for the team. This education programme includes coaches and referees for two reasons, firstly to ensure the people most essential in protection of players are informed and secondly that the information is filtered down to players. The introduction of the 'RugbySmart' programme reduced scrum-related spinal injury risk by 89% in New Zealand while other injuries that were reduced include knee injuries by 21%, and leg injuries by 19% [96]. Even though injuries were reduced, it may be due to the correct implementation of current laws and a better understanding of times of high risk rather than RugbySmart changing any laws of the game.

A similar programme was introduced in South Africa in 1920, "BokSmart". BokSmart, similarly to RugbySmart began as an information dissemination tool that focused on ensuring coaches and referees were provided with evidence-based understanding of injuries and how to best prevent injuries [15]. It went further to describe how to manage play of the game as well as injured and non-injured players. Similar to RugbySmart, BokSmart continued to develop new mechanisms for injury prevention. One of these strategies is known as BokSmart *Safe Six* [97], which focuses on exercises to strengthen commonly injured regions of the body. Since the implementation of the BokSmart Programme, Evidence has suggested that there has been a 40% reduction in injury risk in youth rugby [15]. While BokSmart focuses on training of coaches and referees and the dissemination of information, they do have groups of researchers producing information regularly on different topics such as concussion management [98].

In adult players law changes also represent an effective way of reducing injury. Changes to the scrum engagement law reduced biomechanical load on the spine, particularly the cervical spine, resulting in a reduction in cervical spinal injuries of 44% (absolute difference=0.8 injuries/100,000 players) in adult rugby [99]. Change to tackle laws, including laws prohibiting tackling above the waist, have also targeted illegal tackles, and the height of the tackle by redefining high tackle categories [100]. This has seen a decrease in catastrophic injuries in rugby, specifically cervical spine injuries [101].

There is little guidance on preventative strategies in the literature, although law changes could be one of the most effective means of reducing injury since compliance with laws is mandatory. Combining law changes with developmental milestones or other preventative strategies such as the TRIPP, will allow coaches and match officials to use evidence-based information to assist the implementation of amended rugby laws with players, particularly young players, to reduce possible injuries. However, a preventative programme such as TRIPP considers the injury, rather than development, thus its predictive qualities are based on children already having sustained injuries, rather than predicting injury (and the potential protection offered by laws) based on developmental milestones, which is what this study attempts [95].

2.6. Occupational disruption due to rugby injuries

Occupational disruption is a short-lived and temporary disturbance of someone's usual occupational pattern, caused by reversible internal issues such as injury in sport [4]. Injuries inherent in any contact sport, especially rugby, therefore place children and adolescents at risk for disruptions to their occupations. The time away from play is used as a descriptor or rating for the severity of these even though this rating is subjective and ambiguous.

What this descriptor does not consider is the time away from other occupations as a result of injury. Children who sustain concussion as a result of a contact sport have been reported to need time away from other occupations such as school [102], but this has not been described for other injuries, or for rugby-specific injuries.

This research is therefore important to consider the influence the laws of rugby are having on the developing skeletal system to ensure the schoolboys are placed in the lowest possible risk for an injury and subsequently lower the potential for occupational disruption.

2.7. Conclusion

In South Africa many schoolboys engage in rugby during their school career. Rugby, as a contact sport, however, contains a high level of potential risk for injury. Although this risk of injury is not disproportionate to other sport including American Football and Baseball, it does pose an increased amount of risk as it has less protective gear.

A variety of injuries have been described, both for contact sport in general [21,22,43,45,51,54] and rugby specifically [6,8,74,103]. Some of the injuries affect the skeletal system. Since schoolboys are still developing, the risk of an injury to a non-fused bone may be high, with potentially life-long consequences [104]. It is for this reason then that the laws of rugby should be adapted taking cognisance of the developing skeletal system.

This review highlighted the paucity of literature describing how rugby laws propose protecting the developing skeletal system. There is a significant gap in the literature matching developing bones most at risk at different ages, and which laws of rugby could be adapted to increase protection of developing bones. This is of concern as an injury to the developing skeletal system may have an impact on further development of the bone [104] but furthermore, a fractured bone may additionally result in occupational deprivation [4].

The next chapter (methodology) will describe how this research project will use Framework Analysis to generate a matrix to compare rugby laws and the developing body to identify potential risk of injuries. It will continue to describe how to use the matrix to specifically analyse the developing skeletal system and laws of schoolboy rugby in South Africa.

CHAPTER 3 METHODOLOGY

This chapter describes the method that was followed to execute the research. Firstly, the research design was discussed, followed by a discussion of the research process, the data collection process, data analysis and finally ethical considerations for this project.

3.1. Research Design

The study design used in this research was qualitative desktop review using Framework Analysis as a method of analysis between July 2018 and February 2019. Framework Analysis was an applied research approach which focused on predetermined themes and codes to interpret information [105]. It was developed to address specific questions as an applied research approach that was useful for informing both policy and practice [106]. Therefore, Framework Analysis was an appropriate method for this study which used seminal texts to extract data and deductive coding basing themes and codes on pre-existing literature rather than a retrospective analysis of reported injuries as rugby research so often has done [6,8,60,74,107–111].

The advantages of Framework Analysis were that it used a straightforward approach [112] which provided transparent results and conclusions that could be traced back to the data. In this study, Framework Analysis provided the researcher with a process to interpret large amounts of data in a step by step manner. Data could be analysed separately (laws of rugby and bone fusion separately) and crossing themes (comparing laws of rugby and age of fusion) could be combined in the final analysis [113]. It further provided easy retrieval of data and allowed for large amounts of data to be easily summarised (large amounts of seminal data on fusion of bones) and reviewed. Framework Analysis allowed for the provision of a new structure for the data in answering the research question using steps described in this chapter. It provided a framework for the use of predetermined codes, while it provided clarity on the integration of the codes [114]. Data relating to the skeletal development of children and adolescents which were aligned to the laws of rugby from the South African Rugby Union (SARU) and World Rugby (WR) for children aged 5 to 18 years old were extracted. This data was systematically analysed to establish the risk for injury in schoolboy rugby players.

One concern however for Framework Analysis might have been that highly heterogenous data cannot be analysed well within this methodology. However, this was not of concern in this study as even though the laws of rugby and the skeletal development of children were not homogenous in nature, they were used to determine one new manner in which to analyse previously heterogenous information and align it with each other [106]. Furthermore, many critiques of qualitative data included the lack of rigour with which the data was reviewed however, Halstead, McAvoy, Devore, Carl, Lee and Logan[106], described rigour and quality review of the information sources as a requisite in Framework Analysis. This was a further support for Framework Analysis as the methodology for this study.

The process of Framework Analysis occurred in the following four steps, as described by Spencer and Ritchie [105] in the context of this study.

Defining concepts:

STEP 1: FAMILIARISATION (Data Analysis)

- Once all information was charted, the researcher systematically analysed the information according to key dimensions and themes.

Mapping range and Nature of phenomena:

STEP 2: INDEXING (Data Analysis)

- The researcher identified the ends of the range of information which included: the 6 adapted laws which were included and the grouping of bones.

Creating typologies:

STEP 3: CHARTING (Data Analysis)

In this process two or more points were linked to give new dimensions such as at age 5 when rules are incorporated only two bones in the skull are fused.

- Identification of the age groups most at potential risk for injury was also done in this stage.

Finding associations:

STEP 4: MAPPING AND INTERPRETING (Results- Chapter 4)

- In this part the researcher looked for patterns of associations that arose throughout the literature. This included adolescents being at higher potential risk for injury due to their fusion occuring so late and no rule adaptation.

Proving explanations:

STEP 4: MAPPING AND INTERPRETING (Discussion -Chapter 5)

- In this section the researcher looked to address the objectives to determine whether the laws of rugby protected schoolboys playing rugby and which laws increased the potential risk for injury.

Developing strategies:

- Conclusion and Recommendations (Chapter 6):
  - In this section the researcher developed recommendations to increase the safety of the sport. The researcher also highlighted considerations that should be taken when the game is played at different ages.

Figure 3.1: Framework Analysis in the context of this study

3.1.1. Familiarisation

The process of familiarisation was used to gain a general understanding of the available information and to determine which information was needed and would fit the inclusion criteria variables or did not fit the study and would therefore form part of the exclusion criteria. The familiarisation process followed the three steps: consultation with experts on paediatric development and rugby, review of suggested seminal texts and determining of inclusion and exclusion criteria and finally, tabulation of seminal texts. This therefore allowed for the data to be appropriately extracted.

3.1.1.1. Expert guidance on seminal texts

In order to streamline the data collection, experts on schoolboy development and osteology were consulted to provide guidance regarding the seminal texts on the topic of bone development in children and adolescents aged 6 to 18 years. Experts could be described as being in the top of his or her field, which was achieved through formal training, experience and research in this field [115] and could also include individuals with at least 10 years of extensive practice in a specific field [116].

Two sets of experts were consulted in this study, i.e. skeletal and schoolboy rugby experts. Skeletal experts were conveniently and snow-ball sampled [117] from the University of the Witwatersrand for consultation. Five experts who had at least 10 years of experience in the field of paediatric development and lecture in the area of either musculoskeletal development or paediatric development were included in the study (Table 3.1).

Table 3.1: Inclusion and exclusion of experts - development and osteology

Professional category	Included or excluded	Reason for inclusion or exclusion	Seminal texts suggested
Physiotherapist 1	Excluded	• While this potential expert is an expert in musculoskeletal injuries in sportsmen, she lacks expertise regarding paediatric development.	n/a
Physiotherapist 2	Included	• Expert in musculoskeletal development of children • More than 10 years' experience • Lecturer of paediatric physiotherapy	Development across the life span [118]
Anatomical scientist 1	Included	• Expert in paediatric skeletal development • More than 10 years' experience • Lecturer of anatomical science	Human Osteology [119]
Anatomical scientist 2	Included	• Expert in paediatric skeletal development • More than 10 years' experience • Lecturer of anatomical science	Developmental Juvenile Osteology [120]
Occupational Therapist	Excluded	• Lecturer of paediatric occupational therapy • More than 10 years' experience • Excluded based on lack of enough knowledge of bone development in children and adolescents	n/a

Participants who had insufficient knowledge of bone development, or who were unable to view rugby from an occupational lens were excluded. Potential experts considered included two physiotherapists, two anatomical scientists and one occupational therapist. Reasons for their inclusion or exclusion, and seminal texts they suggested can be seen in Table 3.1. The physiotherapist who was excluded referred the researcher on to another physiotherapist with expertise in skeletal development and children. While the occupational therapist lectures in paediatric occupational therapy and had a large repertoire of paediatric knowledge, she was excluded as an expert in this study, since she was unable to view this research from an occupational lens and had insufficient knowledge about bone development in children.

Simultaneous to meeting with experts on skeletal development, the researcher met with an expert in schoolboy rugby. This expert's information was presented in Table 3.2 The expert in rugby coaching and refereeing guided the researcher to gather the laws of rugby from the following: http://www.worldrugby.org/lawregulations/laws/index.html. [2] for adult laws and the adapted laws for South African primary and high school rugby players from https://www.sareferees.com/laws/law-book/ [1]. The 2018 laws were considered in this study. These laws were then placed into a table (Appendix B) where it was easy to identify which laws had variations for primary and high school players and which laws did not.

Table 3.2: Inclusion of expert - schoolboy rugby laws

Professional category	Included or excluded	Reason for inclusion or exclusion	Seminal texts suggested
Rugby coach and referee	Included	• Able to provide expert advice on laws of rugby, including adaptations for primary and high school laws and refereeing of these ages. • More than 10 years' experience in coaching and refereeing in South Africa	WR Law Book SARU primary school law adaptations

3.1.1.2. Review of seminal texts

Once consultations with experts in specific fields occurred, a list of seminal books was generated by the researcher (Appendix C). In this stage the researcher read the texts to first deeper understanding of development and rugby and then to confirm the suitability of the books (Human Osteology [119] and Developmental Juvenile Osteology [120]). These books were then included/ excluded based on a specific criterion set (inclusion and exclusion criteria) developed by the researcher through reading the texts and discussions with the supervisor (Table 3.3).

Table 3.3: Inclusion and exclusion criteria for seminal texts

Inclusion criteria for seminal texts	Exclusion criteria for seminal texts
- Must include development of the entire skeletal system - Must include fusion of each bone as a reference point of maturation - Must be written in English	- Vagueness or lack of detail on bone development in children and adolescents

Once the inclusion and exclusion criteria were confirmed and the books were deemed suitable the researcher ensured that no information was missing from the available seminal texts by completing a literature search using the key words (Sport, Sport in children, Sport injuries, sport Injuries and children, Rugby, Rugby injuries, Rugby injuries and children, Development of bone, Fractures, Broken Bones) and having discussions with the supervisor. By gaining an overview of the information the researcher was able to then tabulate all the information from the seminal text in the last stage of familiarisation.

3.1.1.3. Tabulation of data from seminal texts

Once the seminal data had been reviewed, a table including all the bones in the skeletal system and their age of fusion was created. This table can be found in Appendix E. The laws of rugby were reviewed and tabulated into a separate table from the suggested documents and websites. In the laws of rugby there were five adapted laws which were excluded from this study, these laws and reasons for exclusion are presented in Table 3.4.

Table 3.4: Adapted rugby laws excluded

Law	World Rugby Law	Adapted Law	Reason for exclusion
1	Ground: There are dash lines configured as shown in the ground diagram. Each dash within a dash line is five metres in length. There are dash lines: - Five metres from, and parallel to each touchline. - 15 metres from, and parallel to, each touchline. - 10 metres from, and parallel to, each side of the half-way line. - Five metres from, and parallel to, each goal line.	- The dash lines parallel to the touchlines at 5m are replaced with dash lines running 3m from the touchlines. - The dash lines parallel to the touchlines at 15m are replaced with dash lines running 13m from the touchlines."	The primary school law makes the field of play smaller; this adaptation does not have a clear impact on bone fractures but may affect the cardiovascular system instead.
3	Team: Replacement of players: - For international matches, a union may nominate up to eight replacements. For other matches, the match organiser decides how many replacements may be nominated, up to a maximum of eight.	Up to eight (8) players may be replaced during a game. This must include three (3) front row players (Loose head prop, Hooker & tight head prop) who are suitably trained for these positions.	The primary school law adaptation increases the number of players which may be included and specifies which position they should be trained in. This law focuses on the cardiovascular system rather than the skeletal system While the substitution brings in a protective element for the front row players, the basis for this is unclear.
5	Time: A match lasts no longer than 80 minutes (split into two halves, each of not more than 40 minutes plus time lost), unless the match organiser has authorised the playing of extra time in a drawn match within a knock-out competition.	U9 to U12: Two halves of 20 minutes running time. U13: two halves of twenty-five (25) minutes running time. A maximum of five (5) minutes will be allowed for half-time.	The primary school law makes the length of play shorter; this is protective for the cardiovascular system rather than the skeletal system

Law	World Rugby Law	Adapted Law	Reason for exclusion
8	Conversion kicks: Takes the kick in the field of play on a line through the place where the try was awarded, parallel to the touchlines.	For U9 and U10 age groups, conversion kicks for tries scored between the 13m line and touchline shall be taken on the 13m line.	The primary school law makes the area of play smaller; this adaptation does not have a perceived impact on development as the players are required to kick a shorter distance.
9	Unfair play: Do anything that may lead the match officials to consider that an opponent has committed an infringement.	Add: A player must not create the impression at the tackle that he is being played in the air by jumping over a player.	As this law adaptation speaks directly to the tackle phase of play it was incorporated for ease of analysis into the tackling law.

After the bones of the developing skeletal system and the laws of rugby were tabulated in their individual tables (Appendix B and Appendix E) the process of indexing began.

3.1.2. Indexing

The second process that then followed was indexing and the initial stages of data analysis. Indexes (smaller pieces of similar information grouped together) were used to sort data to identify stages of development that occurred together and laws of rugby which occurred at different ages. Once all the information was placed into separate tables in familiarisation, information that belonged together e.g. all the laws that were introduced to the five-year-old schoolboys were indexed together. This indexing was applied to the framework to allow for a deeper analysis of common themes.

The indexes allowed the researcher to generate a list of key ideas (Table 3.5) to determine the themes of “Bone development and maturation from birth to adulthood” and “Rugby law adaptations for children and adolescents” during the indexing phase.

Table 3.5: Identifying a thematic framework:

Key ideas on bone development	Key ideas on laws of rugby
Nature of bone growth	Age at which laws implemented
Impact of injury of growth plates	Law adaptations
Age at fusion of bones	Law adaptations that place bones at risk
Long bones vs flat bones, bone density, width, strength	Non adapted laws that place bones at risk

This iterative analysis process allowed the researcher to identify *descriptive* codes for the which formed the basis of this analysis. Table 3.6 describes the *descriptive* codes used for skeletal development; Table 3.7 describes the *descriptive* codes used for law adaptations.

Table 3.6: Themes, Categories and Codes for Matrix development: Bone Development

Theme	Category	Key Codes
Bone development and maturation from birth to adulthood	Skeletal development including the presence of growth plates and bone fusion.	Age at which fusion occurred: • Skull • Vertebral column • Upper limb including the shoulder and hand • Lower limb including the pelvic girdle and foot

Table 3.7: Themes, Categories and Codes for Matrix development: Bone Development

Theme	Category	Key Codes
Rugby law adaptations for children and adolescents	Ages of play and law variations • Primary School • High school	Age at which law or law adaptation is implemented • Law 2 (Ball) • Law 4 (Clothing) • Law 16 (Maul) • Law 18 (Touch, quick throw and line out) • Law 19 (Scrum)
	Not adapted for school rugby	• Law 14 (Tackling)

The framework was then developed according to the key codes described above through the process of charting.

3.1.3. Charting (Development of a matrix depicting alignment of laws of rugby and age of fusion of bones of the skeletal system)

This step consisted of lifting information from the "original context and rearranged according to appropriate thematic reference" [105]. This was done to place all the relevant information from the separate tables into one framework (Figure 4.1) as seen in the results chapter. In this stage of analysis, the researcher used the determined themes and codes to understand possible integration and associations between information and whether the information is being used correctly in situation or not. For each bone the age at which it is fused as well as the age that adapted laws were introduced were charted as well as the number of laws impacting on the given bone.

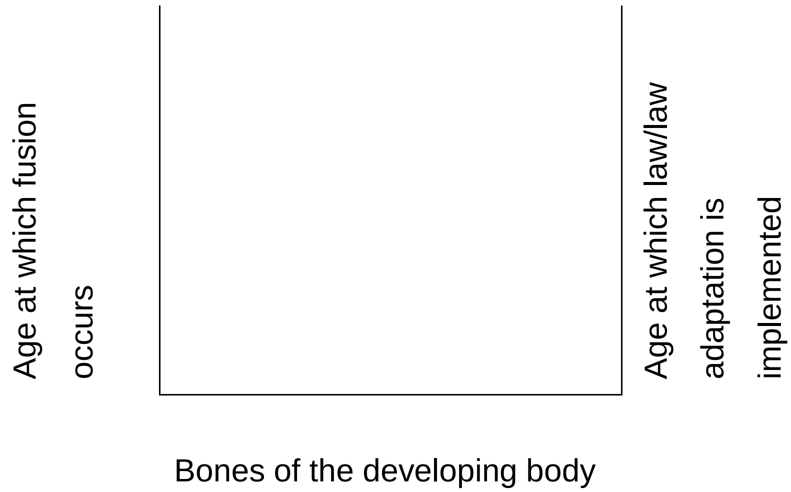

Figure 3.2: Integration of the themes and key codes

3.1.4. Mapping and Interpreting (Development of a mathematical equation to determine potential risk of injury for each bone)

During the mapping and interpreting stage of this research the researcher ensured the six key objectives of analysis were completed in steps 1-3 through ensuring all relevant information was available for further interpretation.

Once all the relevant information was available as seen in Figure 4.1 it highlighted which laws and law adaptations are implemented before fusion occurs, thus posing potential risk to a developing bone. The researcher however predicted there is an inflated potential risk of injury if each adaptation is considered a separate law rather than considering the assumed protective nature of having an adaptation to the law. Therefore, a further iterative process of analysis was needed to develop a weighting scale of potential risk of injury.

The simple weighting scale was to account for the laws which had adaptations as being safer while those that have no adaptations were considered less safe. The weighting scale was then used to allocate a weighting to the different laws of rugby which are included in this study. The laws and weighting allocated to each law can be seen in Table 3.8.

Table 3.8: Laws and weighting scale for number of adaptations

Law	Number of law adaptations	Weighting scale assigned
Ball	2	3
Clothing	2	3
Maul	2	3
Touch, Quick Throw, line out	2	3
Tackle	0	5
Scrum	4	1

The weighting scale as shown in Table 3.8 provides a greater weighting to those laws which provide no adaptations to the law while reducing the weighting on those laws with multiple adaptations. This weighting scale was included in a formula to determine the potential risk of injury for each bone based on the weighting on the law.

The following formula was developed to calculate the potential risk of injury:

Equation: Potential risk of injury based on weighting of laws

$$\text{Potential risk of injury} = \frac{(\text{Age of fusion} + \text{sum of the weighting of laws acting on the bone})}{\text{Number of laws acting on the bone}+1}$$

The outcomes based on this step of the analysis are presented in Chapter 4 and 5 as results and discussion and Chapter 6 as recommendations.

3.2. Ethical considerations

This research was desktop research and as such an ethical waiver for this research was granted by the Human Research Ethics Committee (Medical) of the Faculty of Health

Sciences of the University of the Witwatersrand as it did not involve human research participants. Ethical waiver number: W- CBP- 180816-3 (Appendix D).

3.3. Control of bias

In this research study bias was mitigated in a number of ways. Confirmation bias were mitigated through applying the principles of trustworthiness in qualitative data analysis, i.e. debriefing with the supervisor, to involve experts in the selection of seminal texts and by application of inclusion and exclusion criteria for both experts and seminal texts [121].

Including all bones and all laws from the start of the study helped to mitigate selection bias [122].

3.4. Conclusion

This chapter critically described the method followed to gather the data required to address the research objectives, i.e. Framework Analysis. In the next chapter the results will be described.

CHAPTER 4 RESULTS

4.1. Introduction

This chapter presents the results of the study in relation to the two objectives of this study, namely the development of a matrix to analyse the risks selected laws of rugby at schoolboy level pose to bone development and the potential risk of playing rugby on the developing skeletal system based on the current laws. First, the development of the matrix for analysis will be described, followed by the laws of rugby which place the developing skeletal system of children and adolescents at potential risk for injury, and thus occupational disruption based on the Framework Analysis described in Chapter 3, Figure 3.1.

4.2. Development of a matrix depicting alignment of laws of rugby and age of fusion of bones of the skeletal system

The matrix was developed by first analysing the literature to identify important concepts in relation to bone development and maturation in humans and secondly by analysing the Rugby Laws to identify which laws may potentially place a developing bone at risk. 4.2.1. Theme 1: Bone development and Maturation

Bone development and maturation from birth to adulthood was initial theme/construct for the matrix in this study. Although there are many body structures developing simultaneously such as muscles, tendons, ligaments etc. bone development was considered an important starting point as it provides the framework which supports all other body structures as they develop. For the purpose of this study, ossification, or fusion of growth plates was considered the key variable used to determine bone maturation, since damage to the growth plates of bones may have significant implications for further development [45]. Fusion of growth plates is considered the end point of bone development and is the point at which the bone reaches it optimum structural development and strength [120]. Fusion occurs at the same point in development which is an important consideration in attempting to determine the potential risk of injury rugby may have on children and adolescents. The consequences of an injury to a bone that has not fused or reached maturation will be greater than the consequences of an injury to a bone that has matured

[45]. Other body structures such as muscles, tendons, ligaments associated with the skeleton were excluded in the Framework Analysis for this study.

Table 3.6. in Chapter 3 provides a broad outline of the skeletal components considered for bone development and maturation from birth to adulthood [120].. A worked example from Appendix E can be seen below in table 4.1 below.

Table 4.1: A worked example from Appendix E showing bone development and maturation.

		Age in years	0-1	2	3	4	5	6	7
Skeletal development of bone	Skull	Frontal bone	1-2 years anterior fontanelle closed		2-4 years: metopic suture closed and fusion complete				
		Parietals	childhood: gradually takes on the appearance of the adult bone as the eminence becomes less obvious						

4.2.2. Theme 2: Rugby Laws

The second theme/construct analysed in the matrix considered the laws of rugby as formulated by World Rugby [2], the official regulating body of Rugby. While cognisance was given to laws that have been adapted for children, laws regulating dangerous playing situations, e.g. tackling, were included, irrespective of whether they were adapted for children or not.

This theme provided an understanding of what occurs in the laws of rugby. Two sets of adaptations were included, namely the Primary School Adaptations [1] and Under 19 Law Adaptations [2].

As described in Chapter 2 above, Rugby has 21 laws with multiple sub-laws, which regulate play (see Tables 2.1- 2.3).

Once the laws of rugby were summarised into tables (Table 2.1 – 2.3) and a understanding of the different types of laws was developed, they were analysed according to those which did and did not have age group law adaptations as described for primary school [1] and under 19 players [2] and dangerous play for all rugby players. The law variations for the components of rugby which literature indicates skeletal injury [8,55,65] is more likely to occur were used to create categories within each age group and identify key codes. The key codes then used to develop the matrix were: Law 2 (Ball), Law 4 (Clothing), Law 14 (Tackle), Law 16 (Maul), Law 18 (Touch, quick throw and line out) and Law 19 (Scrum) as seen in Table 3.7.

Based on the key codes in Table 3.7, the adaptation for each law or the potential risk of injury if the law was not adapted was analysed. An outline of the analysis is presented in Table 4.2.

Table 4.2: Key codes described

	Law	Adaptations of laws to protect players	High potential risk of injury in law
2	Ball (The size, shape and weight of the Ball)	Primary school – a size 4 ball is used until age 13	Size 4 ball is used which is smaller in size but not described as weighing less
4	Clothing (The type of uniforms and additional gear allowed and not allowed to be worn)	Primary school children- all children must play barefoot. Mouthguard are recommended but are not compulsory unless playing a provincial tournament	Children playing without shoes have no protection over the bones of their feet
16	Maul (Competing for the ball which is held off the ground by at least one player from each team while in the field of play)	Primary School: A maul may only move ten (10) metres before the referee will instruct the players to play the ball. If after 5 seconds the ball does not come out a scrum will be awarded for safety.	The binding together around the ball-carrier to move the ball-carrier and the ball towards the scoring line.
18	Touch, quick throw and line out (Method of restarting play when a ball has gone beyond the boundaries line by either a touch, quick throw or line out)	Primary School: All seven (7) suitably trained forward players (positions 1, 3 to 8) must form the line-out but are only required to throw the ball three (3) metres rather than the five (5) metres of adults. The player catching the ball must jump and must not be lifted. He may not be tackled upon returning to the ground.	The lifting and returning of a receiver in the line out from the ground.
19	Scrum (A Manner in which play is restarted after stoppage or a minor infringement but the binding of two teams in a crouched position. The teams then push to get possession of the ball)	Primary School: Adaptations for scrumming range from a 3-man uncontested scrum with a maximum of 10 player to a 5-man uncontested scrum with a maximum of 15 players. High School: Full scrum formation with pre-scrum binding and a maximum of one and a half (1.5m) metre pushing. (full variations can be found in the World Rugby Laws of rugby)	Danger in the scrum for both sides including the forces in a scrum up to 1.5 tonnes and the dangers of a scrum collapsing.
	Law	No adaptations of laws for players	High potential risk of injury in law
14	Tackle (The ball carrier is held by an opposing player and brought to the ground in a safe, fair manner)	No adaptations	The actions of persons involved in tackling including the tackler and the tackled, what a tackle should be and when a tackle should end.

The key codes then used to develop the matrix were: Law 2 (governing the size and weight of the ball), Law 4 (governing uniform and additional gear), Law 14 (governing tackling), Law 16 (governing mauls), Law 18 (governing the ball going into touch, resulting in a quick throw-in and line-outs), and Law 19 (governing the scrum).

Law 2 (Ball) was selected as it is adapted but provides incomplete detail, since the weight differentiation between the smaller ball and larger ball is not described. The weight of the full-size ball is described, though.

Law 4 (Clothing) was selected as it includes playing barefoot in children which is adapted in primary school and not in high school.

Law 14 (Tackle) governs an aspect of dangerous play as the literature describes that most injuries occur in the tackling situation. It was selected since tackling is considered a dangerous aspect of the game, and a high number of tackles occur during a rugby match. Despite it governing dangerous play, it has not been adapted for younger players.

Law 16 (Maul) was selected due to the uncontrolled nature of the play and the impact this may have on potential risk for injury.

Law 18 (Touch, quick throw and line out) was selected as it is adapted but may still pose risk for injury when a player is returning to the ground and lastly Law 19 (Scrum) was selected due to the high potential risk for injury and the multiple adaptations made to increase the safety of phase of play.

These six laws were then incorporated into developing the matrix for analysis to determine whether there is a match or mismatch between the laws of rugby and the protection of the developing skeletal system. As described in Table 3.5 of Chapter 3 laws which did not pose a risk to bones (adapted and non-adapted) were not included as key codes but were rather excluded based on their assumed protective nature.

As seen in Figure 4.1 a matrix was created using the two sets of data with the adaptations to the laws of rugby superimposed onto the development of the skeletal system or any component of the developing body which may be researched in future studies. This matrix allowed the researcher to clearly identify areas where the developing body with unfused bones could be at risk for potential injury due to a match or mismatch to laws in children and adolescents.

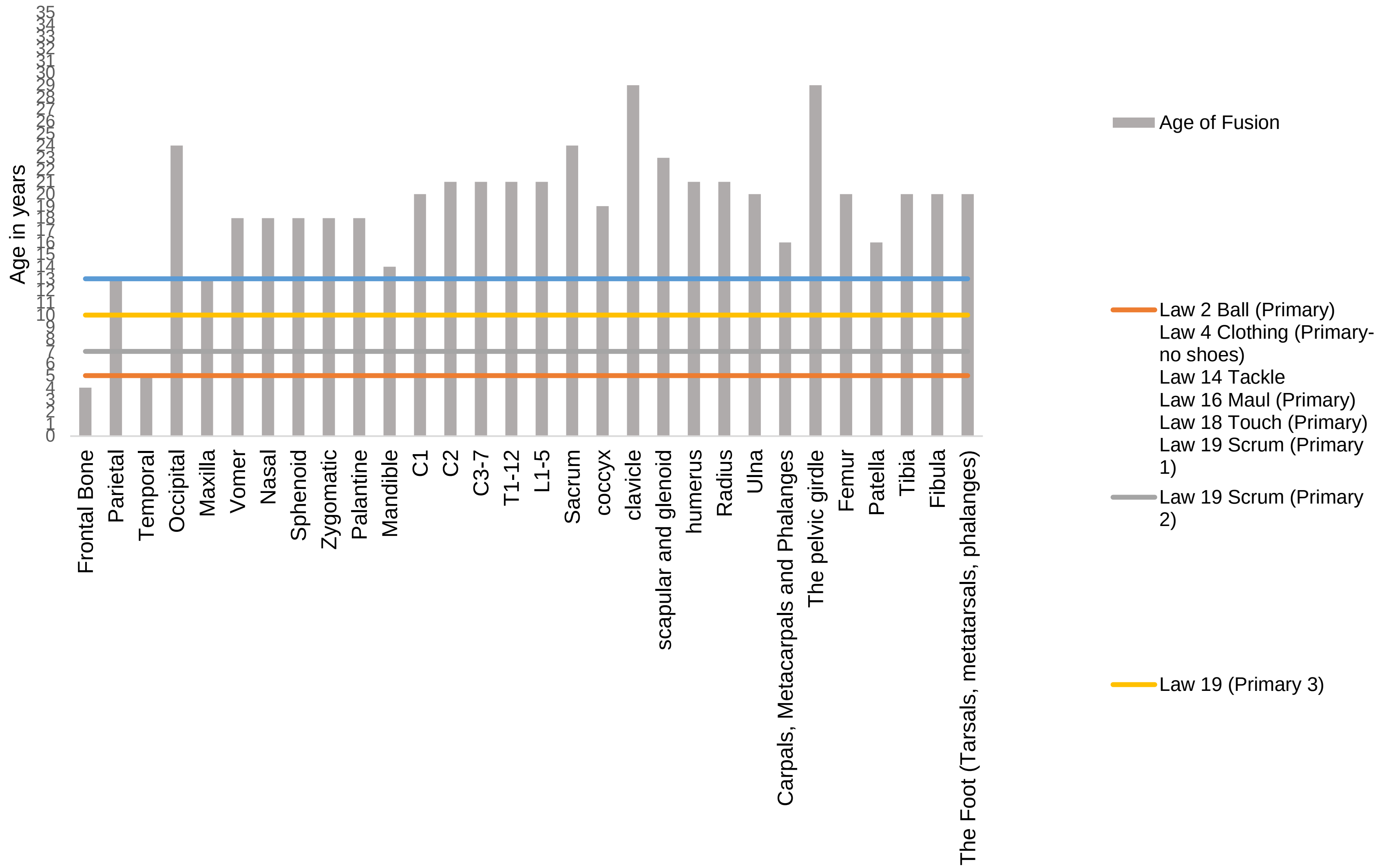

Figure 3.1: A Matrix depicting alignment of laws of rugby and age of fusion of bones of the skeletal system

The matrix for the key codes is presented in Figure 4.1 to identify the potential risk of injury to the developing skeletal system. This allowed the researcher to determine the age group of players for whom the difference of laws of rugby are adapted in relation to the age at which bone fusion occurs according to the players stage of development and maturation from birth to adulthood.

Figure 4.1 2 indicates that fusion occurs for most body parts at an age when adapted rugby laws are no longer in use for a specific age group (older than 18 years). Only the frontal and temporal bones are fused when the primary school laws for tackling, ball use, mauling, touch, quick throw and line out and 3-man binding, and uncontested scrums are introduced at the age of 5 years. At 13 years only the parietals and maxilla bones are fused when the under 19 law adaptations are introduced for, ball, clothing, maul high school touch quick throw and line out and full scrum formation at the age of 13 years. Many bones only fuse after the age of 19 years when adult rugby laws apply. These include the occipital bone, the vertebral column and some bones of both the upper and lower limb. This matrix was used to determine the potential risk for injury to schoolboys while playing rugby.

The matrix which was developed from the themes to meet objective one which was to develop a matrix for the analysis of bone development in children in relation to the adapted laws of rugby is depicted in Figure 4.1.

The section above began by describing how a matrix can be developed for other components of the developing body and ended with the matrix depicting the developing skeletal system and WR laws of rugby. The analysis of this matrix will be used in the next section to determine the potential risk for injury while playing rugby.

4.3. Identification of the potential risk of playing rugby on the developing skeletal system.

In order to identify the potential risk of playing rugby on the developing skeletal system, an iterative process of data analysis was followed as described in Step 4 of Framework Analysis described in Chapter 3 [105]. Figure 4.2 was used to analyse the potential risk of injury to the developing body in terms of age of fusion and adaptation to the law which protects the skeletal system. It highlights which laws and law adaptations are implemented before fusion occurs, thus posing potential risk to a developing bone.

4.3.1 Severity of Potential Risk of Injury

Figure 4.2 indicates the fusion for each bone in relation to the number of adapted and non-adapted laws acting on it. However, for further analysis to occur a table indicating the number of laws acting on each bone was needed. An example of the analysis can be seen in Table 4.3 with the analysis for each bone found in Appendix F.

Table 4.2: Number of laws acting on each bone

		Law 2 (Ball)	Law 14 (Tackling)	Law 16 (Maul)	Law 18 (Touch, quick throw and line out)	Law 19 (Scrum)	Total number of laws acting on the bone
Bone	Frontal bone	0	1	1	0	1	3
	Occipital bones	0	1	1	0	1	3

The number of laws acting on each bone provided the researcher with an understanding of which laws acted on the bones but did not provide a severity rating for each bone. To determine a rating of severity a quotient was calculated for each bone and the number of adaptations of each law acting on it.

The severity of the of injury was determined by the sum of Age of fusion of specific bone subtracted from the Age of law implementation of specific law and dividing it by number of laws acting on the specific bone.

Eq**uation 1: Potential risk of injury based on laws**

$$\text{Potential Risk of Injury} = \frac{\text{Sum of (Age of fusion of specific bone – Age of law implementation of specific law)}}{\text{Number of laws acting on the specific bone}}$$

The values from the severity of potential risk of injury calculations can be seen in Appendix G**.**

However, once potential risk of injuries for each bone was indicated, to determine a meaningful distribution between mild, moderate and severe potential risk of injury quotients were further interpreted with age ranges. From this interpretation, the severity rating of mild, moderate and severe (Figure 4.3) was understood as:

- Mild: A quotient potential between -5 and +5 and an age range of 4 years – 13 years old
- Moderate: A quotient potential between +6 - +10 and an age range of 14 years – 18 years
- Severe: A quotient potential between +11-+22 and an age range of 19 years – 30 years

An important consideration to the laws which are included in the matrix is Law 14 (Tackle) as it has no adaptation but does however pose a significant risk for injury.

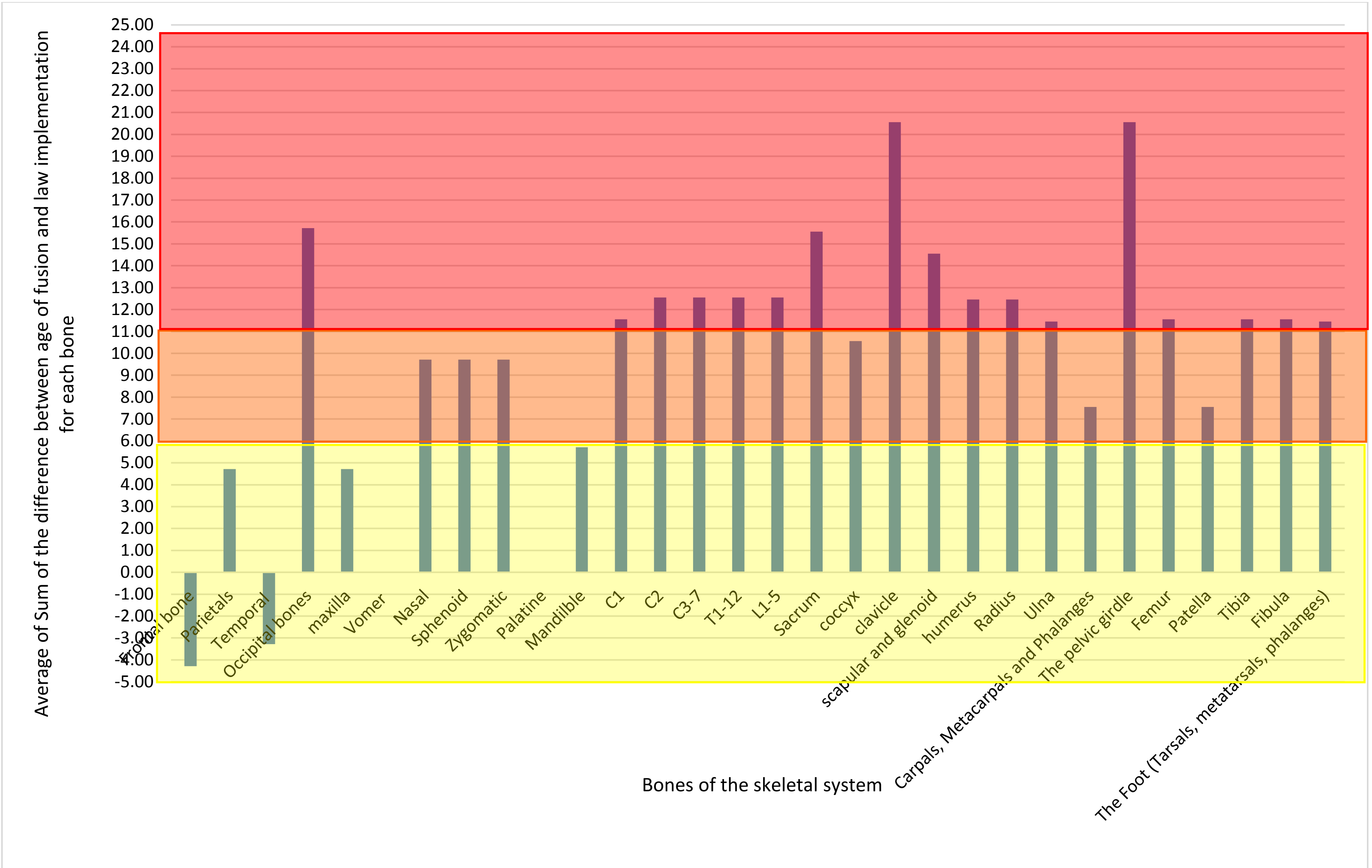

Figure 4.3: The potential risk of injury for each bone according to the number of adapted and non-adapted laws acting directly on the bone

Once the initial analysis had been done, it was determined that there was an inflated potential risk of injury as each adaptation was considered a separate law rather than considering the assumed protective nature of having an adaptation to the law. Furthermore, equation resulted in negative values which were not possible to relate to severity and were therefore not meaningful. Therefore, a further iterative process of analysis was needed.

The iterative process of analysis was done by implementing a simple weighting scale which accounted for the laws which had adaptations as being safer while those that have no adaptations as less safe. The weighting scale was then used to allocate a weighting to the different laws of rugby which are included in this study. The laws and weighting allocated to each law can be seen in Table 4.4.

Table 4.4: Laws and weighting scale for number of adaptations

Law	Number of adaptations	Weighting scale assigned
Ball	2	3
Clothing	2	3
Maul	2	3
Touch, Quick Throw, line out	2	3
Tackle	0	5
Scrum	4	1

The weighting scale as shown in Table 4.4 provides a greater weighting scale to those laws which provide no adaptations (e.g. tackling) to the law while reducing the weighting on those laws with multiple adaptations. This weighting scale was included in an adapted formula to determine the potential risk of injury for each bone based on the weighting on the law.

The following formula was developed to calculate the potential risk of injury:

Equation 2 Potential risk of injury based on weighting of laws

$$\text{Potential risk of injury} = \frac{(\text{Age of fusion} + \text{sum of the weighting of laws acting on the bone})}{\text{Number of laws acting on the bone} + 1}$$

The potential risk of injury scores each bone received can be found in Appendix H.

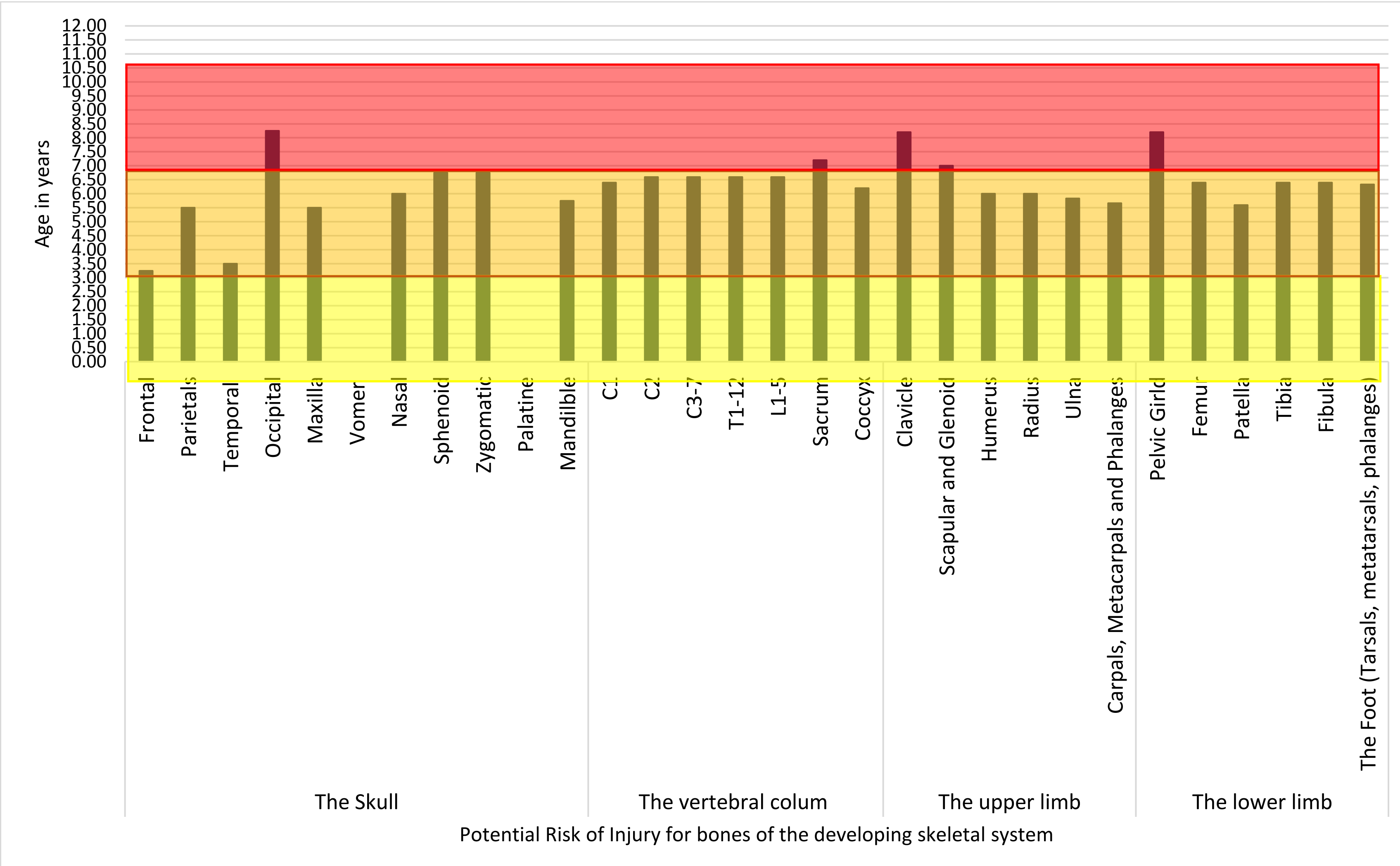

Figure 4.4: Potential Risk of Injury of bones with weighted laws

The weighting of the laws incorporates the assumed protective nature of the law and therefore a provided a more concise understanding of the potential risk of injury for each law. This can be seen in Figure 4.4.:

Figure 4.4 indicates that a mild, moderate and severe potential risk of injury for the bones may be different for the different bones but use of the weighting scale for laws incorporates the assumed protective nature of the law and therefore provides a better understanding of the potential risk of injury for each bone. A rating scale of mild (0-3.50), moderate (3.51-7.00) and severe (7.01 and above) was used to determine potential risk of injury descriptor will be used to group bones as discussed below.

4.3.1.1. Mild potential risk for injury

Figure 4.4. indicates four bones scored mild potential risk for injury, these bones are the vomer, palatine, frontal and temporal bones of the skull.

The vomer and palatine bones scored zero for their potential risk of injury. This value indicates that while the bones both fuse later in life (vomer at age 30 years and palatine at age 16 years) there are no laws acting on them directly while playing rugby as they are deep lying structures of the skull and therefore only at mild potential risk for injury.

The frontal bone fuses at age 4years therefore they are fused prior to primary school rugby beginning but the weighting of the laws acting on them increase the potential risk of injury.

The temporal bone also fuses at 5 years of age which is prior to primary school rugby beginning. However, just as the frontal bone 3 laws act on the bone which increases the potential risk of injury to mild.

4.3.1.2. Moderate potential risk for injury

Bones which scored a potential risk of injury score between three and a half and seven have a moderate potential risk of injury. This range includes more of the bones of the skeletal system which can be understood as these bones have some protective mechanisms (either law adaptations or fusion of bones).

In the skull the parietal, maxilla, nasal, sphenoid, zygomatic and mandible bones are all at moderate potential risk of injury. The parietal and maxilla bones both fuse at 13 years of age which indicates they are protected by fusion in high school whereas the nasal, sphenoid and zygomatic bones fuses at 18 years old indicating that this will occur in the last year of high school.

In the vertebral column, fusion occurs initially at the coccyx, then vertebrae C1 to L5 and finally the sacrum. These bones fuse later in the adolescent years between 19 years and 25 years with majority of the bones fusing at 21 years old. These bones are at moderate potential risk due to the late age of fusion.

In the upper limb, the bones of the hand (carpals, metacarpals and phalanges) fuse at 16 years old; these bones are the earliest to fuse in the upper limb. These bones therefore have a protective mechanism as they fuse early. The bones of the arm and shoulder (humerus, ulna, radius and scapular and glenoid) fuse between 20 and 23 years old and therefore are at a moderate potential risk of injury as they as the bones are not fused in primary and high school and are essential in playing rugby.

In the lower limb the bones of the patella fuses first at the age of 16 years old followed by the femur, tibia, fibula and bones of the foot which occurs at 20 years of age. These bones are all at moderate risk of injury with a score of 7.25 and the patella and foot has a slightly lower score of 6,2. These bones are therefore at moderate risk for injury as they have an extended period of time where fusion has not occurred while play is occurring.

There are many bones with a moderate potential risk of injury as the mean age of fusion is 18.9 years old. The high mean age of fusion indicates that these bones may be at moderate potential risk of injury as fusion has not occurred while the laws are being played.

4.3.1.3. Severe potential risk for injury

Figure 4.7 indicates there six bones are at severe potential risk for injury; these bones are bones of the skull (occipital bone), the sacrum of the vertebral column, the clavicle and the pelvic girdle of the lower limb. These bones scored a potential risk quotient between seven and above indicating a severe potential risk of injury.

The occipital bones of the skull have a severe potential risk for injury; the occipital bone being the bone with the greatest potential risk of injury. The occipital bone only fuses at 25 years old therefore there is a large amount of time between when adaptations are no longer applied, and fusion occurs, placing the occipital bone and underlying structures at a high potential risk of injury. The sphenoid and zygomatic bones both fuse at 18 years old. While these bones are at a severe potential risk of injury due to the lateness at which they fuse and the number of laws acting on them, they are not as at risk as the occipital bone.

The sacrum fuses at 24 years old therefore there are no law adaptations which are acting on the sacrum and therefore it is not protected. The sacrum is therefore at a severe potential risk of injury due to the age at which it fuses.

The clavicle in the upper limb has a potential risk of injury of 8,2 which is the same as the pelvic girdle. The clavicle and pelvic girdle both fuse within the 29th year of life and are integral in many aspects of the game. Therefore, these two bones will be at potential risk of injury for a player’s full career prior to fusing occurring and therefore why they are in the severe potential risk of injury category.

It can be seen from the matrix that there is a range of potential risk of injury to the developing skeletal system that extends from mild to severe and is continuous in a rugby player’s life until 30 years old. This therefore means that there appears to be a predictive potential risk of injury based on the above matrix which indicates a mild, moderate and severe potential risk of injury for bones of the developing skeletal system.

4.4. Conclusion

This chapter described the development of a matrix to analyse bone development in children and adolescents in relation to adapted rugby laws (objective 1). This chapter described which laws of rugby place the developing bones at mild, moderate and or severe risk for potential injury based on the age of fusion and the adaptation of rugby laws to increase protection of children and adolescents (objective 2). It can be seen from this chapter that the laws of rugby do not consider the rate of fusion of bones in children and adolescents when implementing adapted laws of the game and age of fusion can be used as a predictor for potential injury. In the next chapter a discussion about the implications of the apparent mismatch will be covered.

CHAPTER 5 DISCUSSION

5.1. Introduction

This chapter draws together the results in Chapter 4 and the current literature available both locally and internationally. It considers the objectives to develop a matrix to determine potential risk of injury as well as the severity rating of potential risk of injury for schoolboy rugby players.

5.2. Development of a matrix

The first objective of the study was to develop a matrix through Framework Analysis as described in Chapter 3 and shown in Chapter 4. The main finding of this objective was that a matrix can be used easily to interpret large amounts of text data to determine the potential risk of injury on the developing body through an intersection between development and laws of sport.

This matrix provides an easy to understand visual representation of when substantial developmental events occur (e.g. bone fusion) and which laws of sport either protect development or place the developing component and greater risk for injury. This matrix is a benefit of Framework Analysis as it is a fluid process that allows for the inclusion of other, previously not analysed, information for easy interpretation [123].

Predicting potential injuries before they occur is an attempt to make the sport safer for the developing skeletal system (and other systems). There is a distinct advantage of having a matrix with which to compare the impact of potential law changes before they are even implemented. Through developing the matrix, it was found that tackling, which is not adapted for children, places children at the greatest risk of injury [8,65,74]. This is confirmed in the literature, based on tracking injuries after they occurred. However, research done after children and adolescents are injured does not allow for the elimination of occupational disruption. Having a matrix with predictive value, therefore, could prevent occupational disruption and enhance occupational participation, not only in sport, but also other occupations.

This study found that while laws have been adapted for children at least at two junctures, i.e. primary school and high school levels, juxtaposing the laws of rugby with bone development, highlighted a misalignment between the law adjustments and when bones fuse. To our knowledge, this is the first time that this juxtaposition has been done, thus there is a paucity of literature comparing injuries to law adjustments.

As a researcher the model provided an opportunity for eye-balling [124] to determine a trend which was used to develop a classification of severity of potential risk to players. The use of the matrix and the potential risk for injury will be discussed next.

5.3. The potential risk of playing rugby on the developing skeletal system.

Using a combination of age at fusion and number of law adaptations, this study found that the various bones in the developing body are at different levels of risk of potential injury. Based on the equation discussed in Chapter 4, the potential of injury was classified in to mild, moderate and severe risk of injury. In this section Figure 4.5 will be used to discuss the mild, moderate and severe potential risk of injury to the developing skeletal system.

5.3.1. Mild potential risk for injury

This study showed four bones to have a mild potential risk for injury; the vomer, palatine, frontal and temporal bones scored between zero and three and a half for their potential risk of injury rating, using this study's equation

5.3.1.1. The skull

5.3.1.1.1. Frontal bone

The frontal bone, while it has a mild potential risk of injury due to the early age of fusion (4 years old), it has seven laws which act on it. Nonetheless, it is not commonly described as being fractured often in literature. Rather, literature described frontal bone fractures as rare at only 1.8% [125] when described in relation to sport. While frontal bone fractures are rare due to the force needed to damage the frontal bone [126], frontal bone fractures may be associated with concussions which is a common injury in contact sport and specifically in rugby [98,127,128]. The findings of this study therefore seem to agree with the literature regarding the likelihood of fractures of the frontal bone, but it does not address vulnerabilities of underlying structures.

5.3.1.1.2. Temporal bone

The temporal bone fuses at five years old which is protective as it means that it is fused prior to primary school rugby beginning. The literature appears to agree that this bone is seldomly injured as there is no literature with regards to temporal fractures generally, or in sport literature. This research however determined that there is a mild potential risk of injury for the temporal bone which is therefore not supported by the literature. One argument for the temporal bone to have a mild potential risk of injury is that, when fused, it is thinner than other regions of the skull placing it at a greater risk of injury [126] in rugby where there are many collisions with other players, the ground and the equipment which are the main causes of injuries to the head and neck in sports with a ball such as rugby [52]. However, no injuries are reported in the literature, therefore, this supports the temporal bone as a mild potential risk of injury due to the injuries which may occur.

5.3.1.1.3. Vomer

The vomer has no potential risk of injury, this may be explained by the vomer having very few laws acting directly on it even though fusion occurs very late at the age of 30 years old. The potential risk of injury score of zero is in line with literature on facial fractures, more specifically nasal fractures which do not mention the vomer as a fracture which occurs [52,125,129,130]. It is likely, however that the lack of potential risk of injury to the vomer is more likely due to the situation/location of the bone rather than the protectiveness of the laws of rugby.

5.3.1.1.4. Palatine

Similarly, the palatine bone scored zero for the potential risk of injury. The palatine bone fuses at 16 years of age, which is earlier than the vomer bone but relatively late in comparison to other bones of the skeletal system such as the frontal bone. Again, literature does not describe fractures of the palatine bone [52,125,129,130] which may be due to the situation/location of the bone which protects against injury and the laws of rugby may not be influencing the potential risk of injury.

The four bones (the vomer, palatine, frontal and temporal) have a mild potential risk of injury for different reasons, including their situation/location in the body and limited number of laws acting directly on the bones. Therefore, the mild potential risk of injury determined in Figure 4.5 is correct for these bones and this figure can be seen as predicting the correct severity rating for these bones.

5.3.2. Moderate potential risk for injury

This study showed some of the bones of the skull (Temporal, nasal, parietal, maxilla and mandible), vertebral column (C1- L5 and coccyx), upper limb (humerus, radius, ulna and hand) and lower limb (femur, patella, tibia, fibula and foot) have a moderate potential risk for injury, using this study's equation.

5.3.2.1. The skull

In the skull the nasal, parietal, maxilla, sphenoid, zygomatic and mandibular bones are all at moderate potential risk of injury however the range of potential risk of injury differs with the mandible bone being the highest. In this section, the bones will be discussed in ascending order of potential risk of injury starting with the parietal, maxilla, mandible, nasal, sphenoid and zygomatic bones.

5.3.2.1.1. Parietal bone

The parietal bone has many similarities with the temporal bone as together they are often referred to as the temporo-parietal area of the skull. Fractures of the parietal bone in children are rare and when they do present it is generally with regards to trauma as a result of large amounts of force [126]. These fractures are also rare in sport and specifically rugby because phases of play where the parietal bone is acted on specifically are few (players falling on another player's head is rare). It can be argued then that the parietal bone should have a lower potential risk of injury than the frontal bone (mild potential risk of injury), however Yoganandan and Pintar (2004) found that there is a lesser force needed to damage the temporo-parietal region of the skull than is needed to damage the frontal bone and therefore placing it at a greater risk of injury is justifiable [126].

5.3.2.1.2. Maxilla bone

The maxilla bone has a moderate potential risk of injury as seen in Figure 4.6. While the maxilla is an underlying structure that fuses at 13 years old (the first year of high school in South Africa) and has high school adapted laws acting on it, it is not a commonly fractured bone in sport [125]. However, when this bone does break it can have serious complications and requires hospitalisation [130]. A fracture of the maxilla bone requires a significant force due to the location of the bone and the supporting structures around the bone. The lack of commonality of the injury may be because it fuses prior to adolescence when the boys are bigger and stronger which may normally increase the number of injures [5]. Another possible reason for the lack of injuries is that the laws which possess the most force (the scrum) has protective adaptations in the forming of a scrum during primary school which protects the non-fused bone.

5.3.2.1.3. Mandible bone

The mandible has a moderate potential risk of injury. . The mandible fuses at age 14 which is after the first year of high school in South Africa. This indicates that the mandible is at risk for injury until second year of high school. The mandible is however commonly injured [125] in contact sports and therefore the potential risk of injury for the mandible should be considered high.

5.3.2.1.4. Nasal bone

The nasal bone was found to have a moderate potential risk of injury as it only fuses at 18 years old and has many aspects of rugby which may lead to a fracture of the nasal bone and therefore many laws acting on it. The nasal bone does however have law adaptations implemented in both primary school and high school, which ought to serve as a measure of protection. However, the nose in humans is a prominent facial feature and is subsequently commonly injured [130,131], and is commonly fractured in children and adolescents [130–132]. It should be noted however that there is no literature describing nasal fractures in rugby specifically and therefore the exact comparison of number of injuries and potential risk of injury for rugby is not possible. There is a dearth of research indicating a specific incidence of nasal injuries, either in rugby specifically, or in contact sport in general, thus it is difficult to establish whether the moderate risk rating in this study aligns with the literature.

5.3.2.1.5. Zygomatic and Sphenoid Bone

The zygomatic and sphenoid bones are very similar in nature; the two bones fuse at 18 years old, are impacted by three laws and have a potential risk of injury score of 6.75. This is of interest as the moderate potential risk of injury of these two bones is in line with literature for the zygomatic bone but not for the sphenoid bone. A study by Delilbassi et al. (2004) on sport with balls found that the most common midface fractures were the zygomatic bone and arch [52]. Similarly, Antoun and Lee (2008) found that the zygomatic arch was second most commonly fractures bone in sport related facial fractures [125]. This is therefore in line with the zygomatic bone's potential risk of injury.

The sphenoid bone however is not in line with the literature as there is a dearth of literature regarding sphenoid bone fractures. The sphenoid bone is often considered part of the nasal bone [131] which may influence reported injuries. Additionally, due to the deep orientation of the bone, fractures are very rare [125].

5.3.2.2. The vertebral column

In this study the vertebral column not only includes the vertebrae but also the coccyx which develops with the vertebra to form the vertebral column of the body. These three groups of bones all have a moderate potential risk of injury in children and adolescents according to this study and will be discussed separately.

5.3.2.2.1. Vertebrae

The vertebrae of the cervical, thoracic and lumber region all fuse between the ages of 20 and 21 years old. Therefore, age of fusion occurs after high school in South Africa traditionally ends, and consequently after high school law adaptations have concluded. Law adaptations are therefore only protective of unfused bones until the age of 18 years old when the law adaptations stop, and adult laws are applied.

Surprisingly, the number of vertebral injuries are low when compared to other injuries and has reduced since 2001 [133], however they can have a significantly greater impact on occupational participation than other injuries.

Vertebral injuries can range from catastrophic spinal cord injuries to minor sprains [101]. In this study, the vertebrae received a severity rating of moderate due to the late age of fusion and the number of laws acting on it. However, due to the protective nature of the law adaptations such as the formation of the scrum the vertebrae bones are protected and this is seen in literature by a decrease in the number of injuries occurring and the reduction in catastrophic injuries [72,133,134].

The vertebral column may further be protected by the later fusion in life. The vertebral column is flexible and continues to have flexibility until it is completely ossified therefore fusion after primary and high school may be protective [135].

The vertebral column however may not be protected as the neck is often used to decelerate the body when hitting an object which is further influenced by small vertebral bodies and weak muscles reducing the protection [136] of the bones. Furthermore, vertebral injuries occur most often during the tackle and not the scrum as previously thought [65,136,137] which is the one law which is not protected by law adaptations and therefore supports the findings of this study.

The vertebrae are therefore at a potential risk of injury because while the bones are protected by their development and later fusion, they are most commonly injured during a phase of play such as mauls that has no law adaptations and is therefore may not be protective.

5.3.2.2.2. Coccyx

This study found that due to the late age of fusion (between 19 years old) the coccyx is at moderate potential risk of injury. This is not supported by the number of injuries in literature. Injuries to the coccyx are very rare and seldom appear in literature on acute injuries [138]. One reason for this is may be that the sacrum and coccyx are normally incorporated into the trunk when speaking about injuries and not discussed individually [139] or that the rate of injury is so low there is no need to differentiate it as an injury [138].

5.3.2.3. The upper limb

The bones of the hand (carpals, metacarpals and phalanges) fuse at 16 years old and therefore have a protective mechanism as they fuse early. The humerus, ulna, radius and scapular and glenoid bones do not fuse until the early 20s and therefore do not have the protective mechanism. Injuries of the upper limb may take longer to heal as they cause the greatest time loss away from sport of all injuries [6] however, there is no consistent percentage of injuries to the upper limb in rugby. This may be due to the difference in grouping of bones of the upper limb, for example in this study the bones of the hand are grouped together whereas in other studies they are discussed separately [140] and where this study separates the humerus, ulna and radius other studies refer to the upper extremity in its entirety [48]. The difference in groupings of bones may affect the correlation between the potential risk of injury determined in this study and the literature available.

5.3.2.3.1. Hand

The bones of the hand (including the carpals, metacarpals and phalanges) fuse up to 16 years old and are therefore the first bones of the hand to fuse. This may be protective as the bones are fused prior to the last two years and arguably the most competitive years of high school rugby [7]. However, this is not what is seen in the literature; in the literature the phalanges and metacarpals of the fingers are the second and third most commonly fractured bones in sports related fractures [140]. Although they are the second and third most commonly fractured bones when playing rugby, these fractures are approximately 50% less than the amount of clavicular fractures that occur [103]. Injuries to the hand and fingers are also shown to be more severe than injuries to other bones in the body[55], which indicates that both the frequency of the injury and the severity of the injury are high. This does align to the moderate severity this study found for the bones of the hand but may be related to the high complication rate in had fractures due to the involvement of other anatomical structures in the hand and the proximity of all soft tissue to the bones [141].

5.3.2.3.2. Scapula and Glenoid

The scapular and glenoid bones of the upper limb scored a potential risk of injury score of 8 due to the age of fusion, which is 23 years old, and the number of laws acting on the bones. These bones however are not spoken about individually but rather grouped together as the shoulder and therefore there is no consensus in literature regarding how often fractures occur in this region. Shoulder fractures are also very rare in the literature [140] however shoulder dislocations are more common especially with adolescents [21]. While shoulder dislocations are not common in the paediatric population, contact sport is leading to an increase in younger, shoulder dislocations [142] The potential risk of injury for this study therefore does not align with the literature for fractures however it does align that there is a high percentage of dislocation injuries which were not considered in this study. This potential risk of injury may therefore be indicating a broader potential risk of injury to regions of the body which are heavily involved in the game of rugby such as the shoulder.

5.3.2.3.3. The Arm (humerus, ulna and radius)

The humerus and radius fuse at the age of 21 years old whereas ulna fuses at the age of 20 years old therefore the ulna is at slightly higher potential risk of injury. The difference of one year of fusion does not however see any significant differences in the number of injuries sustained to each bone. Humerus fractures are uncommonly seen and are seldom [48] written about in literature regarding sports. The fact that humerus injuries are not specifically mentioned, could be attributed to the inclusion of the humerus into groupings such as with the shoulder or upper extremity [48,55,140]. The moderate potential risk of injury for the humerus from this study is appropriate though because the humerus is a vital link between the shoulder and the forearm and subsequently the wrist. Injuries to any of these areas will therefore influence the humerus. The humerus is also influenced by many rugby laws and therefore has many forces of play acting on it. It is therefore a moderate potential risk of injury.

Similarly, the ulna and radius are at a moderate potential risk of injury due to the age at which fusion occurs and the number of laws acting on these two bones. The moderate potential risk of injury is supported by literature where the radius and ulna are fourth most likely bone to be injury when playing rugby [140], interestingly though the distal radius and ulna are at a higher potential risk of injury than the proximal radius and ulna. This study however looked at the bones in their entirety rather than different aspects of the bone and this may have an influence on the potential risk of injury.

5.3.2.4. The lower limb (Femur, Tibia, Fibula, Patella and Foot)

5.3.2.4.1. Femur, Tibia and Fibular

The femur, tibia and fibula scored a moderate potential risk of injury. These three bones all fuse at 20 years of age, when the law adaptations no longer apply. Similarly, to the upper limb, the bones of the lower limb are seldom referred to separately in literature regarding fractures due to sport [140]. Furthermore, the literature seems to rather be reporting soft tissue injuries, e.g. strains and tears [6].

In a study by Wood et al. (2010) the fractures sustained from different sports were researched; femur fractures were not found in rugby however tibia and fibula fractures were found at 6.2% of the rate of injuries [140]. With such a small rate of fractures occurring there appears to be a mismatch between this study's moderate potential risk of injury score when the actual injury is occurring so infrequently; however, a fracture to the lower limb will remove a player from the game for an extended period of time and this can impact return to play. It is therefore important to not only consider the age of fusion and law adaptations when predicting injuries.

5.3.2.4.2. The Patella

The patella has a moderate potential risk of injury with a score of 6.25 which is slightly higher than the potential risk of injury of the foot. In literature however, the patella is seldomly spoken about alone but rather incorporated into knee injuries [58]. Injuries to the knee are seldom fractures, though, and are rather ligament and soft tissue injuries [21]. While the patella is seldomly written about as sustaining a fracture in literature, the surrounding structures are very important for mobility and engagement in occupation. Therefore, an injury to the patella may include the surrounding structures and therefore an injury in this region may be a moderate injury with implications to occupations.

5.3.2.4.3. The Foot

The bones in the foot fuse at 20 years old which is later in life, but the rugby boot protects players from age 13 years and older. Prior to 13 years old, the bones of the foot however are not protected by the boot as the laws adaptation which has primary school players to play barefoot, essentially removes the protection of shoes. Ordinarily, the bones in the foot are protected by a rugby boot while playing rugby but the law adaptation removes this protection. The paucity of literature on foot injuries shows that this is not a well-researched area. Pearce et al. (2011) described how foot injuries account for 4% of all injuries with acute injuries being the most common of those [143]. The low percentage of injury is in line with this literature because although the number is low an injury to the foot may remove a player from the game.

5.3.3. Severe potential risk for injury

This study showed the occipital bones of the skull, the clavicle of the upper limb and lower limb (sacrum and pelvic girdle) have a severe potential risk for injury, using this study's equation.

5.3.3.1. The Skull

5.3.3.1.1. Occipital bone

Similarly to sphenoid fractures, fractures of the occipital bone are very rare, however when they do occur they can be very serious [144]. This study found that the occipital bone has a high potential risk of injury due to fusion only occurring at 24 years old which is very late considering the underlying structures it is protecting, and in comparison, to the age of fusion of other bones. The location of the occipital bone and the underlying structures should be seen as very important to protect, however due to the late fusion and the stopping of adapted laws at the end of high school there is a large period of time where there injury may occur to a non-fused bone.

5.3.3.2. The vertebral column

5.3.3.2.1. Sacrum

This study found that due to the late age of fusion of the sacrum (24 years old) and the many laws acting on it due to the nature of rugby, the sacrum is at a severe potential risk of injury. Injuries to the sacrum, similar to the coccyx, are very rare and are seldom addressed in literature [138]. As the sacrum and coccyx are normally incorporated into the trunk and not discussed individually [139] there may be a dearth of literature on the bones individually or that the rate of injury is so low there is no need to differentiate it as an injury [138]. While this is not supported by number of injuries in literature it is an important consideration in the linking of the sacrum to the vertebral column and the lower limbs. Furthermore, the sacrum is surrounded by a large amount of musculature which may reduce the number of fractures of the sacrum, but rather soft tissue injuries may occur. The rugby literature does not discuss injuries of the sacral area and therefore it may be assumed that although the potential risk of injury based on the equation is high, the likelihood of an injury is low.

5.3.3.3. The Upper limb

5.3.3.3.1. Clavicle

The clavicle scored the second highest potential risk score for this study (together with the pelvic girdle) of 9.5. This high potential risk of injury is due to the late age at which fusion occurs (29 years old) and the large number of non-adapted laws acting on this bone. This potential risk of injury is supported by literature as the clavicle is one of the most commonly fractured bones in children and adolescents [21] even though dislocations become more prevalent as age increases. Wood et al. (2010) similarly found in their study that the most commonly fractured bone in rugby is the clavicle which therefore corresponds with the risk matrix of this study [140].

5.3.3.4. The Lower limb

5.3.3.4.1. Pelvic girdle

The pelvic girdle scored a potential risk of injury score of 9.5 which is one of the second highest scores (together with the clavicle). The pelvic girdle scored such a high potential risk of injury due to its late age of fusion (29 years old) and the number of non-adapted and minimally adapted laws acting on it. The pelvic girdle is essential for playing rugby and is used in both open play (tackling, maul, rucking) and in scrumming and line outs. Therefore, the opportunity for injury to occur to the pelvic girdle is high. However, the literature describing the number of injuries seen in rugby does not align with the high potential risk of this study. This may be because the pelvic girdle is surrounding by many soft tissues including muscles, tendons and ligaments which may protect the pelvic girdle from fractures. Therefore, although the number of fractures may be low, there may be a high number of soft tissue injuries in the hip region [5], but these are beyond the purview of this study.

5.4. Limitations of the study

Although the findings in this study highlight the potential risk to the bones of the developing skeletal system, only one point of measurement was used (fusion). This is a limitation as there may be other factors which influence potential risk of injury positively and negatively such as the development of muscles, tendons, ligaments as well as environmental factors such as socio-economic status and race [145]. Furthermore, this study only considered male age of fusion which therefore excludes females from this potential risk of injury.

Another limitation to the study was that only two seminal texts on skeletal development were used and there may be numerous other texts which have conflicting information. Therefore, the ages of fusion between texts may differ resulting in different potential risks of injuries.

When comparing the results of this study in terms of the potential risk of injury and the actual reported risk of injury, it was found that there is little consistency in how the literature reports on sport injuries in general, and rugby injuries specifically. Many studies report on injuries in a regional manner, i.e. referring to shoulder, upper limb [140], knee or lower limb injuries [146], thus not separating the underlying skeletal structure from the soft tissues surrounding it. This may therefore be a reason for the mismatch between certain bones and the literature.

Finally, as this is the first time Framework Analysis has been used to the researchers knowledge to compare the age of fusion and the laws of rugby to determine potential risk of injury, there may be differing opinions on which measures should and should not be incorporated into this study.

5.5. Conclusion

One of the operational areas of focus in occupational science is the relationship between an occupation and other phenomena [9]. The research direction for this focus includes explaining how occupation relates to human development. This chapter described the unique perspective as outlined in the framework of occupational science knowledge and research directions to determine if the adaptation of a leisure activity, specifically rugby, accommodates skeletal development of schoolboys.

The potential risk of injury in this study increased when many unadjusted laws acted on a bone. One such law is tackling, which acts upon most of the bones in the body and has been described as the phase of play to occur most frequently [147].

When comparing the potential risk identified by this study to the frequency of injuries reported in the literature, there appeared to be agreement between this study's findings and the literature about the nature of risk to the: frontal, vomer, palatine, temporal, parietal, zygomatic, sphenoid and occipital bones of the skull and humerus, radius, ulna and clavicle of the upper limb. There was not agreement between this study and the literature about the potential of injury risk to the: maxilla, vertebrae, sacrum and coccyx, scapular, glenoid and hand in the upper limb and pelvic girdle, femur, tibia, fibula, patella, foot of the lower limb. It was noted that the literature reports on regional injuries, which includes soft tissue injuries, and do not isolate bones when reporting on injuries. This may affect the agreement between this study and the literature. Also, some authors have indicated that injuries are under-reported, which may influence the accuracy of injury rates reported in the literature. Important to occupational therapy, injuries may result in occupational deprivation [4].

This chapter described the development of a matrix to analyse bone development in children and adolescents in relation to adapted rugby laws. This chapter described which laws of rugby place the developing bones at mild, moderate and or severe risk for potential injury based on the age of fusion and the adaptation of rugby laws to increase protection of children and adolescents. This chapter also highlighted the limitations of this study. It can be seen from this chapter that the laws of rugby do not consider the rate of fusion of bones in children and adolescents when implementing adapted laws of the game. In the next chapter a discussion about the implications of the mismatch will be covered.

CHAPTER 6 CONCLUSION

6.1. Introduction

The occupational science understanding of the occupation of playing rugby has been researched with respect to the other phenomenon of skeletal development. From this perspective, this study considered how occupation is controlled within a defined context and how human occupational performance can be affected by the environment in which it takes place. An injury to a developing bone can have a major impact on engagement in occupation both short term in occupational disruption and possibly longer term as occupational deprivation.

This study focuses on the relationship between the occupation of playing rugby and human development of schoolboys and analyses the effect environmental influences related to the laws of rugby may have in terms of occupational disruption.

This chapter summarises the previous chapters, highlighting the methodology of the study, the key findings of the study, and the conclusion of the study. Furthermore, recommendations for future studies, policy and practice will be discussed.

6.2. Conclusion

The purpose of this study was to determine whether the laws of rugby protected skeletal development through their adaptations. Framework Analysis was used as the method to determine whether the laws of rugby protected skeletal development as it allowed large amounts of text data to be summarised and compared. Through interaction with experts in the field of paediatric development and rugby laws, seminal texts which provided the data used in this study. Framework Analysis then allowed for key concepts from seminal texts to be developed into a matrix which the researcher used to further determine potential risk of injury to the developing skeletal system. This matrix allows for any component of development in children, adolescents and adults (e.g. muscular maturation, neurological development etc.) to be compared to the laws of rugby (or any sport with which there are law adaptations) both in South Africa and internationally to determine where the laws of sports intersect with developmental components. This matrix allowed the researcher to determine the potential risk of injuries to bones in the developing skeletal system ranging from mild to severe potential risk of injury. Tackling was identified as the most dangerous law in the game of rugby.

The vomer, palatine, frontal and temporal bones have the lowest potential risk of injury based on this study, due to their early fusion, situation in the body and the number of laws acting on them. The occipital, sphenoid, zygomatic, scapular, glenoid and clavicle bones, as well as the sacrum and pelvic girdle have the highest potential risk of injury. This is due to their late age of fusion and the number of non-adapted laws acting on them.

The law that was found to be most dangerous is tackling and the literature agrees [61]. The forces involved in tackling, especially when a player is running, the frequency at which tackling occurs and the fact that it impacts on almost every bone in the body, make it imperative that this law is considered for adaptation for children at both intersections (i.e. primary and high school).

6.3. Recommendations

6.3.1. Recommendations for practice

While this study focuses on the occupational science and potential occupational disruption which may occur when an injury is sustained while playing rugby (to the skeletal system and to other systems), it is important for occupational therapists to be aware of the danger of sport. This research provides important information that should be highlighted for occupational therapists, namely: the need for advocacy, advising policy, potential injuries to clients and finally the role of occupational therapy in sport, specifically rugby.

The roles of occupational therapists as described in Occupational Therapy: Practice Framework, third edition [148] describes the need for therapists to advocate for the safety of children and adolescents as well as to consult on policy. This research highlighted the bones which are at severe potential risk of injury and should therefore be highlighted not only to the rugby corporations but to other therapists to be aware of the potential dangers of children and adolescents playing rugby. This will ensure an activity such as sport within an occupation (education) is not causing injuries, and therefore potential occupational disruption.

Secondly, occupational therapists should be advising on policies for change to occur, as they are able to use their activity analysis skills to further identify key areas of potential injury.

Thirdly, occupational therapists should be aware of the potential injuries the children and adolescents they are seeing in therapy may sustain while playing rugby and the subsequent occupations which may be disrupted by these injuries.

Finally, occupational therapists should be aware of their important role in the assessment and treatment of individuals who have sustained sport related injuries in general and specifically those associated with rugby. Rugby injuries may lead to a disruption in occupational participation and therefore occupational therapists should be able to provide intervention to ensure that individuals are independent in all occupations as soon as possible.

6.3.2. Recommendations for Rugby

A multitude of recommendations have previously been made in literature, which are echoed in this study. Firstly, World Rugby, or SARU should consider developing a more uniform way of reporting injuries, including making reporting all injuries mandatory and having a central database in which all statistics of injuries should be kept. This would enhance future research into the efficacy of law adaptations to protect developing bodies.

Secondly, World Rugby and SARU should provide more detailed information on the reason, research and decision-making process which is used to determine the adaptations made to laws. This will allow future researchers to understand the changes which have occurred in laws and will allow for a continuous development of laws.

Finally, based on the results of this study, consideration should be given to further evaluation of the laws of rugby. Laws pertaining to tackling in particular should be reviewed to enhance player safety.

6.3.3. Recommendations for future studies

In future studies this matrix should be expanded to include all aspects of development and all laws of rugby to determine the potential risk of injury to the body while playing rugby.

This expanded matrix should be used in future studies to determine what places children and adolescents at the most risk for potential injury to allow for a sound decision on whether laws of rugby should be adapted or whether components should be excluded from the game.

REFERENCES

1. South African Rugby Union. *South African Rugby Union Primary School Law Variations 2018*. 2018.
2. Board. IR. *LAWS OF THE GAME*. 2018.
3. Fuller CW, Molloy MG, Bagate C, et al. Consensus statement on injury definitions and data collection procedures for studies of injuries in rugby union. *Clin J Sport Med* 2007; 17: 177–181.
4. Whiteford G. Occupational deprivation: Global challenge in the new millennium. *Br J Occup Ther* 2000; 63: 5.
5. Patel D, Baker R. Musculoskeletal Injuries in Sports. *Prim Care - Clin Off Pract* 2006; 33: 545–579.
6. Bleakley C, Tully M, O'Connor S. Epidemiology of adolescent rugby injuries: a systematic review. *J Athl Train* 2011; 46: 555–565.
7. Hendricks S, O'Connor S, Lambert M, et al. Contact technique and concussions in the South African under-18 Coca-Cola Craven Week rugby tournament. *Eur J Sport Sci* 2015; 15: 557–564.
8. Freitag A, Kirkwood G, Scharer S, et al. Systematic review of rugby injuries in children and adolescents under 21 years. *Br J Sports Med* 2015; 49: 511–519.
9. Hocking C. Occupational science: A stock take of accumulated insights. *J Occup Sci* 2000; 7: 58–67.
10. Holder MD, Coleman B, Sehn ZL. The contribution of active and passive leisure to children's well-being. *J Health Psychol* 2009; 14: 378–386.
11. Hendricks S, O'Connor S, Lambert M, et al. Contact technique and concussions in the South African under-18 Coca-Cola craven week rugby tournament. *Eur J Sport Sci* 2015; 15: 557–564.
12. Parekh N, Hodges SD, Pollock AM, et al. Communicating the risk of injury in schoolboy rugby: Using Poisson probability as an alternative presentation of the epidemiology. *Br J Sports Med* 2012; 46: 611–613.
13. Freitag A, Kirkwood G, Pollock AM. Rugby injury surveillance and prevention programmes: are they effective? *Bmj* 2015; 350: h1587–h1587.
14. Abernethy L, MacAuley D. Impact of school sports injury. *Br J Sports Med* 2003; 37: 354–355.
15. Brown JC, Verhagen E, Knol D, et al. The effectiveness of the nationwide BokSmart rugby injury prevention program on catastrophic injury rates. *Scand J Med Sci Sport* 2016; 26: 221–225.
16. Sewry N, Verhagen E, Lambert M, et al. Evaluation of the Effectiveness and Implementation of the BokSmart Safe Six Injury Prevention Programme: a study

protocol. *Inj Prev* 2017; 23: 428.

17. Richardson J. Rugby law changes: Proposed measures take heat from fans. *The South African*.

18. Hart ES, Albright MB, Rebello GN, et al. Common Pediatric Fractures — Part I. 2006; 25: 251–256.

19. Browne GJ, Lj Barnett P, Barnett PL, et al. Common sports-related musculoskeletal injuries presenting to the emergency department. *J Paediatr Child Health* 2016; 52: 231–236.

20. Delgado J, Jaramillo D, Chauvin NA. Imaging the Injured Pediatric Athlete: Upper Extremity. *RadioGraphics* 2016; 36: 1672–1687.

21. Rosendahl K. Sports related injuries of the pediatric musculoskeletal system. *Pediatr neuroimaging* 2008; 2008.

22. Keays G, Friedman D, Gagnon I. A 20-Year Comparison of Football-Related Injuries in American and Canadian Youth Aged 6 to 17 Years: A replication study. *Clin Pediatr (Phila)* 2016; 55: 603–613.

23. &NA;, Boutis K, &NA; Common Pediatric Fractures Treated With Minimal Intervention. *Pediatr Emerg Care* 2010; 26: 158–162.

24. Leung FT, Franettovich Smith MM, Hides JA, et al. Injuries in Australian school-level rugby union. *J Sports Sci* 2016; 35: 2088–2092.

25. Burger N, Lambert MI, Viljoen W, et al. Tackle-related injury rates and nature of injuries in South African youth week tournament rugby union players (under-13 to under-18): An observational cohort study. *BMJ Open* 2014; 4: 5556.

26. Nguyen JC, Sheehan SE, Davis KW, et al. Sports and the Growing Musculoskeletal System: Sports Imaging Series. *Radiology* 2017; 284: 25–42.

27. Janssen I, Leblanc AG. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *Int J Behav Nutr Phys Act* 2010; 7: 40.

28. Centers for Disease Control and Prevention. US Department of Health and Human Services Physical activity guidelines for Americans. Atlanta, GA: Centers for Disease Control and Prevention (CDC). *Natl Cent Chronic Dis Prev Heal Promot* 2008; 6–17.

29. Eime R, Young J, Harvey J, et al. A systematic review of the psychological and social benefits of participation in sport for children and adolescents: informing development of a conceptual model of health through sport. *Int J Behav Nutr Phys Act*; 10. Epub ahead of print 2013. DOI: 10.1109/APCC.2016.7581477.

30. Fraser-Thomas JL, Côté J, Deakin J. Youth sport programs: an avenue to foster positive youth development. *Phys Educ Sport Pedagog* 2005; 10: 19–40.

31. Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity. *Med Sci Sport Exerc* 2000; 32: 963–975.

32. Bailey R. Evaluating the relationship between physical education, sport and social inclusion. *Educ Rev* 2005; 57: 71–90.

33. Bailey R. Physical Education and Sport in Schools : A Review of Benefits and Outcomes. *J Sch Health* 2016; 76: 397–401.

34. Quarrie KL, Brooks JHM, Burger N, et al. Facts and values: On the acceptability of risks in children's sport using the example of rugby-a narrative review. *Br J Sports Med* 2017; 51: 1134–1139.

35. Caine D, Purcell L. Injury in pediatric and adolescent sports: Epidemiology, treatment and prevention. *Inj Pediatr Adolesc Sport Epidemiol Treat Prev* 2015; 1–242.

36. Stracciolini A, Casciano R, Levey Friedman H, et al. Pediatric sports injuries: A comparison of males versus females. *Am J Sports Med* 2014; 42: 965–972.

37. Costa e Silva L, Fragoso MI, Teles J. Physical Activity–Related Injury Profile in Children and Adolescents According to Their Age, Maturation, and Level of Sports Participation. *Sports Health* 2017; 9: 118–125.

38. Junge T, Runge L, Juul-Kristensen B, et al. *Risk factors for knee injuries in children 8 to 15 years: The CHAMPS study DK*. 2016. Epub ahead of print 2016. DOI: 10.1249/MSS.0000000000000814.

39. Schwebel DC, Brezausek CM. Child development and pediatric sport and recreational injuries by age. *J Athl Train* 2014; 49: 780–785.

40. Bayt DR, Bell TM. Trends in paediatric sports-related injuries presenting to US emergency departments, 2001-2013. *Inj Prev* 2016; 22: 361–364.

41. Fuller C, Ekstrand J, Junge A, et al. Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. *Clin J Sport Med* 2006; 16: 97–106.

42. Centers for Disease Control. *Sports-related injuries among high school athletes--United States, 2005-06 school year.* 2006.

43. Patel D, Yamasaki A, Brown K. Epidemiology of sports-related musculoskeletal injuries in young athletes in United States. *Transl Pediatr* 2017; 6: 160–166.

44. Dangelmajer S, Grant G, Pan J, et al. Sports-related brain injuries: connecting pathology to diagnosis. *Neurosurg Focus* 2016; 40: E14.

45. Rosendahl K, Strouse PJ. Sports injury of the pediatric musculoskeletal system. *Radiol Medica* 2016; 121: 431–441.

46. Patel DR, Yamasaki Ai, Brown Kelly, et al. Epidemiology of sports-related musculoskeletal injuries in young athletes in United States. *Transl Pediatr* 2017; 6: 160–166.

47. Clain MR, Hershman EB, Goldberg B. Overuse injuries in children and adolescents. *Phys Sportsmed* 1989; 17: 111–123.

48. Merkel D, Molony J. Recognition and Management of Traumatic Sports Injuries in the Skeletally Immature Athlete. *Int J Sports Phys Ther* 2012; 7: 691–704.

49. O'Dell MC, Jaramillo D, Bancroft L, et al. Imaging of Sports-related Injuries of the Lower Extremity in Pediatric Patients. *RadioGraphics* 2016; 36: 1807–1827.

50. Chéron C, Le Scanff C, Leboeuf-Yde C. Association between sports type and overuse injuries of extremities in adults: A systematic review. *Chiropr Man Ther*; 25. Epub ahead of print 2017. DOI: 10.1186/s12998-017-0135-1.

51. Nguyen J, Sheehan S, Davis K, et al. Sports and the Growing Musculoskeletal System: Sports Imaging Series. *Radiology* 2017; 284: 25–42.

52. Delilbasi C, Yamazawa M, Nomura K, et al. Maxillofacial fractures sustained during sports played with a ball. *Oral Surgery, Oral Med Oral Pathol Oral Radiol Endodontology* 2004; 97: 23–27.

53. Lynch K, Kemper H, Turi-Lynch B, et al. Impact sports and bone fractures among adolescents. *J Sports Sci* 2017; 35: 2421–2426.

54. Delgado J, Jaramillo D, Chauvin N. Imaging the Injured Pediatric Athlete: Upper Extremity. *RadioGraphics* 2016; 36: 1672–1687.

55. Kaplan K, Goodwillie A, Strauss E, et al. Rugby injuries: A review of Concepts and Current Literature. *BMJ* 2008; 66: 86–93.

56. International rugby board. IRB Organisation.

57. International Rugby Board. IRB to change name to World Rugby. *News*.

58. McIntosh A. Rugby injuries. *Med Sport Sci* 2005; 49: 120–139.

59. Hendricks S, Lambert MI, Brown JC, et al. An evidence-driven approach to scrum law modifications in amateur rugby played in South Africa. *Br J Sports Med* 2014; 48: 1115–1119.

60. Constantinou D, Bentley A. Injuries at Johannesburg high school rugby festivals. *South African J Sport Med* 2015; 27: 46–49.

61. Hall J, Cancea R, Kemp S, et al. Injury risks associated with tackling in rugby union. *Br J Sports Med* 2010; 44: 159–167.

62. Leung F, Franettovich Smith M, Hides J. Injuries in Australian school-level rugby union. *J Sports Sci* 2016; 35: 2088–2092.

63. Viviers P, Viljoen J, Derman W. A Review of a Decade of Rugby Union Injury Epidemiology: 2007-2017. *Sports Health* 2018; 10: 223–227.

64. Nicol A, Pollock A, Kirkwood G, et al. Rugby union injuries in Scottish schools. *J Public Health (Bangkok)* 2011; 33: 256–261.

65. Burger N, Lambert M, Viljoen W, et al. Tackle-related injury rates and nature of injuries in South African youth week tournament rugby union players (under-13 to under-18): An observational cohort study. *BMJ Open* 2014; 4: 1–7.

66. Fuller CW, Brooks JHM, Cancea RJ, et al. Contact events in rugby union and their propensity to cause injury. *Br J Sports Med* 2007; 41: 862–867.

67. Quarrie KL, Hopkins WG. Tackle injuries in professional rugby union. *Am J Sports Med* 2008; 36: 1705–1716.

68. Roux CE, Goedeke R, Visser GR, et al. The epidemiology of school boy rugby injuries rugby Injuries. *S Afr Med J* 1987; 71: 307–313.

69. Quarrie KL, Hopkins WG, Anthony MJ, et al. Positional demands of international rugby union: Evaluation of player actions and movements. *J Sci Med Sport* 2013; 16: 353–359.

70. Brown JC, Lambert MI, Hendricks S, et al. Are we currently underestimating the risk of scrum-related neck injuries in rugby union front-row players? *Br J Sports Med* 2014; 48: 1127–1129.

71. Brown J, Lambert M, Hendricks S, et al. Are we currently underestimating the risk of scrum-related neck injuries in rugby union front-row players? *Br J Sports Med* 2014; 48: 1127–1129.

72. Hendricks S, Lambert M, Brown J, et al. An evidence-driven approach to scrum law modifications in amateur rugby played in South Africa. *Br J Sports Med* 2014; 48: 1115–1119.

73. Rotem T, Davidson RM. Epidemiology of Acute Injuries in Schoolboy Rugby. *Int Sport J* 2001; 2: 1.

74. Roux CE, Goedeke R, Visser GR, et al. The epidemiology of school boy rugby injuries. *S Afr Med J* 1987; 71: 307–313.

75. Trewartha G, Preatoni E, England M, et al. Injury and biomechanical perspectives on the rugby scrum: A review of the literature. *Br J Sports Med* 2015; 49: 425–433.

76. Fuller C. Catastrophic injury in rugby union: Is the level of risk acceptable? *Sport Med* 2008; 38: 975–986.

77. McManus A, Cross D. *Incidence of injury in elite junior rugby union – a prospective descriptive study*. 2003.

78. Durie RM, Munroe AD. A prospective survey of injuries in a New Zealand schoolboy rugby population. *New Zeal J Sport Med*.

79. King D. Incidence of injuries in the 2006 New Zealand national junior rugby league competition. *New Zeal J Sport Med* 2006; 34: 21–27.

80. Nathan M, Goedeke R, Noakes T. The incidence and nature of rugby injuries experienced at one school during the 1982 rugby season. *South African Med J* 1983; 64: 132–137.

81. Gabbett T. Incidence of injury in junior and senior rugby league players. *Sport Med* 2004; 34: 849–859.

82. Usman J, McIntosh A. Upper limb injury in rugby union football: Results of a cohort study. *Br J Sports Med* 2013; 47: 374–379.

83. Haseler C, Carmont M, England M. The epidemiology of injuries in English youth community rugby union. *Br J Sports Med* 2010; 44: 1093–1099.

84. Palmer-Green D, Stokes K, Fuller C, et al. Match injuries in English youth academy and schools rugby union: An epidemiological study. *Am J Sports Med* 2013; 41: 749–755.

85. McIntosh A, McCrory P, Finch C, et al. Head, face and neck injury in youth rugby: Incidence and risk factors. *Br J Sports Med* 2010; 44: 188–193.

86. Collins C, Micheli L, Yard E, et al. Injuries sustained by high school rugby players in the United States, 2005-2006. *Arch Pediatr Adolesc Med* 2008; 162: 49–54.

87. Antoun JS, Lee KH. Sports-related maxillofacial fractures over an 11-year period. *J Oral Maxillofac Surg* 2008; 66: 504–508.

88. Aitken S, Court-Brown CM. The epidemiology of sports-related fractures of the hand. *Injury* 2008; 39: 1377–1383.

89. Brown J, Lambert M, Van Mechelen W, et al. The incidence and severity of injuries at the 2011 South African Rugby Union (SARU) Youth Week tournaments. *South African J Sport Med* 2012; 24: 49–54.

90. Archbold HAP, Rankin AT, Webb M, et al. RISUS study: Rugby Injury Surveillance in Ulster Schools. *Br J Sports Med*. Epub ahead of print 2017. DOI: 10.1136/bjsports-2015-095491.

91. Herrington L, Horsley I, Whitaker L, et al. Does a tackling task effect shoulder joint position sense in rugby players? *Phys Ther Sport* 2008; 9: 67–71.

92. Finch C. A new framework for research leading to sports injury prevention. *J Sci Med Sport* 2006; 9: 3–9.

93. Gianotti S, Quarrie K, Hume P. Evaluation of RugbySmart: A rugby union community injury prevention programme. *J Sci Med Sport* 2009; 12: 371–375.

94. Finch CF, Gabbe B, White P, et al. Priorities for investment in injury prevention in community australian football. *Clinical Journal of Sport Medicine*. Epub ahead of print 2013. DOI: 10.1097/JSM.0b013e31829aa3e8.

95. Finch C, Gabbe B, White P, et al. Priorities for investment in injury prevention in community australian football. *Clinical Journal of Sport Medicine* 2013; 23: 430–438.

96. Gianotti SM, Quarrie KL, Hume PA. Evaluation of RugbySmart: A rugby union community injury prevention programme. *J Sci Med Sport*. Epub ahead of print 2009. DOI: 10.1016/j.jsams.2008.01.002.

97. SA Rugby. BokSmart Safe Six.

98. Patricios J, Kohler R, Collins R. Concussion in Rugby Literature Review. 2010; 27.

99. Reboursiere E, Bohu Y, Retière D, et al. Impact of the national prevention policy and scrum law changes on the incidence of rugby-related catastrophic cervical spine injuries in French Rugby Union. *Br J Sports Med*. Epub ahead of print 2018. DOI: 10.1136/bjsports-2016-096122.

100. International Rugby Board. World Rugby Player Numbers.

101. Dunn R, Spuy D, Neil R, et al. Rugby and cervical spine injuries – has anything changed? A 5-year review in the Western Cape. *South African Med J* 2010; 100: 235–238.

102. Halstead ME, McAvoy K, Devore CD, et al. Returning to Learning Following a Concussion. *Pediatrics* 2013; 132: 948–957.

103. Aitken S, Court-Brown C. The epidemiology of sports-related fractures of the hand. *Injury* 2008; 39: 1377–1383.

104. Hart E, Albright M, Rebello G, et al. Common Pediatric Fractures — Part I. *Orthop Nurs* 2006; 25: 251–256.

105. Spencer L, Ritchie J. Qualitative data analysis for applied policy research. In: *Analyzing qualitative data*. Routledge, 2002, pp. 187–208.

106. Gale N, Heath G, Cameron E, et al. Using the framework method for the analysis of qualitative data in multi-disciplinary health research. *BMC Med Res Methodol* 2013; 13: 1–8.

107. Browne GJ. Cervical spinal injury in children's community rugby football. *Br J Sports Med* 2006; 40: 68–71.

108. Burger N, Lambert M, Viljoen W, et al. Tackle technique and tackle-related injuries in high-level South African Rugby Union under-18 players: real-match video analysis. *Br J Sports Med* 2016; 50: 932–938.

109. Gardner A, Iverson G, Williams H, et al. A Systematic Review and Meta-Analysis of Concussion in Rugby Union. *Sport Med* 2014; 44: 1717–1731.

110. Maclean J, Hutchison J. Serious neck injuries in U19 rugby union players: An audit of admissions to spinal injury units in Great Britain and Ireland. *Br J Sports Med* 2012; 46: 591–594.

111. Swain M, Lystad R, Pollard H, et al. Incidence and severity of neck injury in Rugby Union: a systematic review. *J Sci Med Sport* 2011; 14: 383–9.

112. Ram M, Campling N, Grocott P, et al. A methodology for a structured survey of the healthcare literature related to medical device users. *Evaluation* 2008; 14: 49–73.

113. Furber C. Framework analysis: a method for analysing qualitative data. *Afr J Midwifery Womens Health*. Epub ahead of print 2014. DOI: 10.12968/ajmw.2010.4.2.47612.

114. Ward D, Furber C, Tierney S, et al. Using Framework Analysis in nursing research: A worked example. *J Adv Nurs* 2013; 69: 2423–2431.

115. Rassafiani M, Ziviani J, Rodger S, et al. Identification of occupational therapy clinical expertise: Decision-making characteristics. *Aust Occup Ther J* 2009; 56: 156–166.

116. Schell B, Schell J. *Clinical and professional reasoning in occupational therapy*. Lippincott Williams & Wilkins, 2008.

117. Creswell J. *Research Design.: Qualitative, Quantitative, Mixed Methods Approaches*. 4th ed. University of Nebraska-Lincoln, 2014.

118. Cech D, Martin S. *Functional Movement Development Across the Life Span-E-Book*. Elsevier Health Sciences, 2011.

119. White T, Black M, Folkens P. *Human osteology*. Academic press, 2011.

120. Cunningham C, Scheuer L, Black S. *Developmental juvenile osteology*.

Academic Press, 2016.

121. Elo S, Kääriäinen M, Kanste O, et al. Qualitative Content Analysis : A Focus on Trustworthiness. Epub ahead of print 2014. DOI: 10.1177/2158244014522633.

122. Keeble C, Law GR, Barber S, et al. Choosing a Method to Reduce Selection Bias: A Tool for Researchers. *Open J Epidemiol* 2015; 5: 155–162.

123. Srivastava A, Thomson S. Framework Analysis : Research Note. *J Adm Gov* 2009; 4: 72–79.

124. Thomas G. *How to do your research project: A guide for students in education and applied social sciences*. Sage, 2017.

125. Antoun J, Lee K. Sports-related maxillofacial fractures over an 11-year period. *J Oral Maxillofac Surg* 2008; 66: 504–508.

126. Yoganandan N, Pintar F. Biomechanics of temporo-parietal skull fracture. *Clin Biomech* 2004; 19: 225–239.

127. Board. IR. IRB Conussion Management.

128. Pollock A, Kirkwood G. Head injuries and concussion in rugby. Briefing to the Rugby Union All Party Parliamentary Group. 2016; 13–16.

129. Wright D, Hoffman H, Hoyt D. Frontal Sinus Fractures in the Pediatric Population. *Laryngoscope* 1992; 102: 1215–1219.

130. Reehal P. Facial injury in sport. *Curr Sports Med Rep* 2010; 9: 27–34.

131. Wright R, Murakami C, Ambro B. Pediatric Nasal Injuries and Management. In: *Facial Plastic Surgery*. 2011. Epub ahead of print 2011. DOI: http://dx.doi.org/10.1055/s-0031-1288931.

132. MacIsaac Z, Berhane H, Cray J, et al. Nonfatal Sport-Related Craniofacial Fractures. *Plast Reconstr Surg* 2013; 131: 1339–1347.

133. Dunn R. BokSmart: medical management of suspected serious acute spinal cord injuries in rugby players. *South African J Sport Med* 2017; 21: 91–96.

134. South African Referee Union. *Scrum law modifications for amateur rugby played within South Africa U9 and younger age groups U10 to U16 age groups Includes provincial school age-group rugby Applies to Mini-rugby and normal rugby*. 2014.

135. Dowdell J, Mikhail C, Robinson J, et al. Anatomy of the pediatric spine and spine injuries in young athletes. *Ann Jt* 2018; 3: 28–28.

136. Kuster D, Gibson A, Abboud R, et al. Mechanisms of cervical spine injury in rugby union: A systematic review of the literature. *Br J Sports Med* 2012; 46: 550–554.

137. McCoy G, Piggot J, Macafee A, et al. Injuries of the cervical spine in schoolboy rugby football. *J Bone Joint Surg Br* 2018; 66-B: 500–503.

138. Tirabassi J, Brou L, Khodaee M, et al. Epidemiology of High School Sports-Related Injuries Resulting in Medical Disqualification. *Am J Sports Med* 2016; 44: 2925–2932.

139. Khodaee M, Currie D, Asif I, et al. Nine-year study of US high school soccer injuries: Data from a national sports injury surveillance programme. *Br J Sports Med* 2017; 51: 185–193.

140. Wood A, Robertson G, Rennie L, et al. The epidemiology of sports-related fractures in adolescents. *Injury* 2010; 41: 834–838.

141. Markiewitz A. Complications of hand fractures and their prevention. *Hand Clinics* 2013; 29: 601–620.

142. Hutchinson M, Leonard J. Shoulder injuries in skeletally immature throwers: Review and current thoughts. *Br J Sports Med* 2010; 44: 306–310.

143. Pearce C, Brooks J, Kemp S, et al. The epidemiology of foot injuries in professional rugby union players. *Foot Ankle Surg* 2011; 17: 113–118.

144. Bonfield C, Naran S, Adetayo O, et al. Pediatric skull fractures: the need for surgical intervention, characteristics, complications, and outcomes. *J Neurosurg Pediatr* 2014; 14: 205–211.

145. Vidulich L, Norris S, Cameron N, et al. Differences in bone size and bone mass between black and white 10-year-old South African children. *Osteoporos Int* 2006; 17: 433–440.

146. Shanmugam C, Maffulli N. Sports injuries in children. *Br Med Bull* 2008; 86: 33–57.

147. Fuller C, Brooks J, Cancea R, et al. Contact events in rugby union and their propensity to cause injury. *Br J Sports Med* 2007; 41: 862–867.

148. American Occupational Therapy Association. Occupational therapy practice framework: Domain & process 3rd edition. *Am J Occup Ther* 2014; 68: S1–S48.

APPENDICES

A- Turnitin Report

Research Report

ORIGINALITY REPORT

%6	%3	%1	%4
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	opus.bath.ac.uk Internet Source	%1
2	open.uct.ac.za Internet Source	<%1
3	bjsm.bmj.com Internet Source	<%1
4	Submitted to University of Wales Institute, Cardiff Student Paper	<%1
5	scholar.sun.ac.za Internet Source	<%1
6	Submitted to University of Dundee Student Paper	<%1
7	Submitted to University of Cape Town Student Paper	<%1
8	Submitted to University of Glamorgan Student Paper	<%1
9	Craig Cunningham, Louise Scheuer, Sue Black.	

B- Table of all the laws and adaptations (an example)

	STANDARD ADULT LAWS FROM WORLD RUGBY UNION	UNDER 19 VARIATION OF LAWS WORLD RUGBY UNION	PRIMARY SCHOOL LAW VARIATIONS 2019
Law 1	The Ground		
	1. The playing surface must be safe.		
	2. The permitted surface types are grass, sand, clay, snow or artificial turf (conforming to World Rugby Regulation 22)		
	3. The dimensions of the playing area are as follows: a. The playing area is rectangular in shape. b. Any variations to these dimensions must be approved by the relevant union for domestic competitions or World Rugby for international matches. c. Where the length of the field of play is less than 100 metres, the distance between the 10-metre lines and 22-metre lines is reduced accordingly. d. Where the width of the playing area is less than 70 metres, the distance between the 15-metre lines is reduced accordingly. e. The perimeter area should not be less than five metres wide where practicable.		
	LINES		
	4. There are solid lines configured as shown in the ground diagram. The solid lines are on: a. The dead-ball lines and touch-in-goal lines. b. The goal lines. c. The 22-metre lines. d. The half-way line. e. The touchlines.		

	5. There are dash lines configured as shown in the ground diagram. Each dash within a dash line is five metres in length. There are dash lines: a. Five metres from, and parallel to each touchline. b. 15 metres from, and parallel to, each touchline. c. 10 metres from, and parallel to, each side of the half-way line. d. Five metres from, and parallel to, each goal line.		The dash lines parallel to the touchlines at 5m are replaced with dash lines running 3m from the touchlines. "The dash lines parallel to the touchlines at 15m are replaced with dash lines running 13m from the touchlines."
	6. There is one line 0.5 metres long that intersects the centre of the half-way line.		
	GOAL POSTS AND CROSSBAR		
	7. When padding is attached to the goal posts the distance from the goal line to the external edge of the padding must not exceed 0.3 metres.		
	FLAG POSTS		
	8. There are 14 flag posts with flags, each with a minimum height of 1.2 metres.		
	9. One flag post is positioned at each intersection of the touch-in-goal lines and the goal lines and one at each intersection of the touch-in-goal lines and the dead-ball lines (eight flag posts in total).		
	10. One flag post is positioned in line with the 22-metre line and the half-way line on each side of the pitch, two metres outside the touchlines and within the playing enclosure (six flag posts in total).		
	OBJECTIONS TO THE GROUND		
	11. Teams must inform the referee of any objections before the match starts.		
	12. The referee will attempt to resolve the issues and will not start a match if any part of the ground is considered to be unsafe.		

C- List of books given by experts

Seminal texts suggested	Included or excluded	Criteria on which decision was made
Functional Movement Development Across the Life [118]	Excluded	Lack of detail on bone development in children and adolescents
Human Osteology [119]	Included	• included development of the entire skeletal system • included fusion of each bone as a reference point of maturation • written in English
Developmental Juvenile Osteology [120]	Included	

D- Ethical Clearance certificate

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL

Human Research Ethics Committee (Medical)

Research Office Secretariat:
Faculty of Health Sciences, Phillip Tobias Building, 3rd Floor, Office 301/2/4, 29 Princess of Wales Terrace, Parktown, 2193
Tel +27 (0)11-717-1252 /1234/2656/2700
Private Bag 3, Wits 2050
Office email: HREC-Medical.ResearchOffice@wits.ac.za
Website: www.wits.ac.za/research/about-our-research/ethics-and-research-integrity/

Ref: W-CBP-180816-3

16/08/2018

TO WHOM IT MAY CONCERN:

Waiver: This certifies that the following research does not require clearance from the Human Research Ethics Committee (Medical)

Investigator: Ms Faye Sinnett (staff no. A0051590)

Supervisor: Matty van Niekerk

Department: Occupational Therapy

Project title: Alignment of the rules of rugby and the neuro-musculoskeletal development of children and adolescents 6-18 years.

Reason: Study is purely normative in nature. No human participants will be involved in the study.

CB Penny

Professor CB Penny

Chairperson: Human Research Ethics Committee (Medical)

Copy – HREC (Medical) Secretariat: Zanele Ndlovu, Charmaine Khumalo and Rhulani Mkansi.

E- Table of all the bones and fusion (an example)

Bones		birth to 1 year	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Skull	**Frontal**	1-2 yrs anterior fontanelle closed	2-4 yrs: metopic suture normally closed																							
	Parietals	childhood: gradually takes on the appearance of the adult bone as the eminence becomes less obvious																								
	Temporal	Growth of tempanic plate and formation of foramen Huschke. Mastoid process forming																								
	Occipital	Fusion of partes laterales to squama			Hypoglossal canal complete excluding pars basilaris	3- 7 years: fusion of pars basilaris and partes lateralis					11-16 years in females: Fusion of spheno-occipital synchondrosis		13-18 years in males: fusion of spheno-occipital synchondrosis										closure of jugular growth plates			
	Maxilla	infancy and childhood: gradual increase in size of body of bone. Increase in size of sinus. Eruption and replacement of deciduous teeth.										all permeant teeth emerged except third molars.														
	Vomer		3-10 years: ossification of perpendicular plate of ethmoid towards vomer								10 - puberty: edges of vomerine groove fuse to form canal								20-30 years vomer normally fused with perpendicular plate of ethmoid							
	Nasal		3 years: superior borders become serrated									puberty: adopts adult morphology and size														
	Sphenoid			year 4 - puberty spehnoidal conchae fused to ethmoid	Dorsum sellae ossified																					
	Zygomatic	2- 3 yrs: adopts adult proportions with serrated frontal										puberty: frontal and temporal processes tuberculum marginale and eminentia orbitalis palpable. Malar tubercle may be obvious in males														

	Palatine		from year 3: perpendicular plate starts to increase in height.		puberty: adult morphology and proportions			
	Mandible	infancy and childhood: gradual increase in size and shape of body of bone. Eruption and replacement of teeth.			all permeant teeth emerged except third molars.			

F- Analysis of the bones and the laws acting on each bone

		Age of fusion	Clothing	Ball	Maul	Touch, quick throw and line out	Tackling	Scrum
The Skull	Frontal bone	4	No	No	Yes	No	Yes	Yes
	Parietals	13	No	No	Yes	No	Yes	Yes
	Temporal	5	No	No	Yes	No	Yes	Yes
	Occipital bones	24	No	No	Yes	No	Yes	Yes
	maxilla	13	No	No	Yes	No	Yes	Yes
	Vomer	30	No	No	No	No	No	No
	Nasal	18	No	Yes	Yes	No	Yes	Yes
	Sphenoid	18	No	No	Yes	No	Yes	Yes
	Zygomatic	18	No	No	Yes	No	Yes	Yes
	Palatine	16	No	No	No	No	No	No
	Mandible	14	No	No	yes	No	Yes	yes
The vertebral column	C1	20	No	No	yes	Yes	Yes	Yes
	C2	21	No	No	yes	Yes	Yes	Yes
	C3-7	21	No	No	yes	Yes	Yes	Yes
	T1-12	21	No	No	yes	Yes	Yes	Yes
	L1-5	21	No	No	yes	Yes	Yes	Yes
	Sacrum	24	No	No	yes	Yes	Yes	Yes
	coccyx	19	No	No	yes	Yes	Yes	Yes
The upper limb	clavicle	29	No	No	yes	Yes	Yes	Yes
	scapular and glenoid	23	No	No	yes	Yes	Yes	Yes
	humerus	21	No	Yes	yes	Yes	Yes	Yes
	Radius	21	No	Yes	yes	Yes	Yes	Yes
	Ulna	20	No	Yes	yes	Yes	Yes	Yes
	Carpals, Metacarpals and Phalanges	16	Yes	Yes	yes	Yes	Yes	Yes
The lower limb	The pelvic girdle	29	No	No	yes	Yes	Yes	Yes
	Femur	20	No	No	yes	Yes	Yes	Yes
	Patella	16	No	No	yes	Yes	Yes	Yes
	Tibia	20	No	No	yes	Yes	Yes	Yes
	Fibula	20	No	No	yes	Yes	Yes	Yes
	The Foot (Tarsals, metatarsals, phalanges)	20	Yes	Yes	yes	Yes	Yes	Yes

G- Potential risk of injury scores from Equation 1 (without weighting)

		Age of fusion	number of laws influencing the bone	Potential risk of injury
The Skull	Frontal bone	4	7	-4.29
	Parietals	13	7	4.71
	Temporal	5	7	-3.29
	Occipital bones	24	7	15.71
	maxilla	13	7	4.71
	Vomer	30	0	0.00
	Nasal	18	7	9.71
	Sphenoid	18	7	9.71
	Zygomatic	18	7	9.71
	Palatine	16	0	0.00
	Mandible	14	7	5.71
The vertebral column	C1	20	9	11.56
	C2	21	9	12.56
	C3-7	21	9	12.56
	T1-12	21	9	12.56
	L1-5	21	9	12.56
	Sacrum	24	9	15.56
	coccyx	19	9	10.56
The upper limb	clavicle	29	7	20.71
	scapular and glenoid	23	9	14.56
	humerus	21	11	12.45
	Radius	21	11	12.45
	Ulna	20	11	11.45
	Carpals, Metacarpals and Phalanges	16	9	7.56
The lower limb	The pelvic girdle	29	9	20.56
	Femur	20	9	11.56
	Patella	16	9	7.56
	Tibia	20	9	11.56
	Fibula	20	9	11.56
	The Foot (Tarsals, metatarsals, phalanges)	20	11	11.45

H- Potential risk of injury scores from Equation 2 (with weighting)

		Age of fusion	Number of laws acting on bone + 1	Potential risk of injury
The Skull	Frontal	4	4	3.25
	Parietals	13	4	5.50
	Temporal	5	4	3.50
	Occipital	24	4	8.25
	Maxilla	13	4	5.50
	Vomer	30	1	0.00
	Nasal	18	5	6.00
	Sphenoid	18	4	6.75
	Zygomatic	18	4	6.75
	Palatine	16	1	0.00
	Mandible	14	4	5.75
The vertebral column	C1	20	5	6.40
	C2	21	5	6.60
	C3-7	21	5	6.60
	T1-12	21	5	6.60
	L1-5	21	5	6.60
	Sacrum	24	5	7.20
	Coccyx	19	5	6.20
The upper limb	Clavicle	29	5	8.20
	Scapular and Glenoid	23	5	7.00
	Humerus	21	6	6.00
	Radius	21	6	6.00
	Ulna	20	6	5.83
	Carpals, Metacarpals and Phalanges	16	6	5.67
The lower limb	Pelvic Girdle	29	5	8.20
	Femur	20	5	6.40
	Patella	16	5	5.60
	Tibia	20	5	6.40
	Fibula	20	5	6.40
	The Foot (Tarsals, metatarsals, phalanges)	20	6	6.33