Sport-related Concussion Incidence and Mechanism of Injury in Male and Female Players at the South African Youth Week Rugby Tournaments:

2011-2018

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Plagiarism Declaration

I, Sheenagh Joan Cardis, hereby declare that the work on which this dissertation is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

……Signed by candidate……….

(Signature)

Date: 09-02-2019

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Table of Contents

List of Tables and Figures

List of Abbreviations

BMI: Body Mass Index

SRC: Sport-related Concussion

U13: Under-13

U16: Under-16

U18: Under-18

SCAT5: Sport Concussion Assessment Tool 5

TRIPP: Translating Research into Injury Prevention Practice

Glossary of Terms

Contact event: Event that results in physical contact between two or more Rugby Union players including: scrums, tackling, line-outs and mauls (1).

Open-play: "*The period after a kick-off, restart kick, free-kick, penalty or set piece and before the next phase, or the period between phases of play, excluding when the ball is dead"* (2).

Line-out: *"A lineout is a set piece consisting of a line of at least two players from each team waiting to receive a throw from touch"*(2).

Rugby Union: A sport involving two teams of 15 players each; that is played on field of 100 metres by 70 metres with goal posts on either end. The objective of the game is to score as many points as possible by passing, kicking, carrying and grounding the rugby ball (1).

Tackle: An event where one or more players (the tackler/tacklers respectively) attempt to obstruct or stop the player carrying the ball (ball-carrier). This may involve bringing the ball-carrier to the ground (1, 3, 4).

Scrum: *"A set piece, normally consisting of eight players from each team bound together in formation"* (2).

Uncontested scrum: *"A scrum in which the team throwing-in gains possession without contest, with neither team being allowed to push from the mark"* (2).

Under-13 age group: "*Players aged 11, 12, or 13, with these players turning 12, 13, and having turned 13 respectively during the year in question"* (5).

Under-16 age group: *"Players aged 14, 15, or 16, with these players turning 15, 16, and having turned 16 respectively during the year in question"* (5).

Under-18 age group*: "Players aged 16, 17, or 18, with these players turning 17, 18, and having turned 18 respectively during the year in question"* (5).

Abstract

Background: Rugby is a popular international sport for male and female youth and adult players (6). Injury incidence including sport-related concussion (SRC) is high in youth rugby (7, 8) . This is concerning as youth are more vulnerable to SRC and take longer to recover from SRC than adults (9, 10). Females are also more susceptible to sustaining a SRC, take longer to recover from SRC and have a higher incidence of SRC complications than men (11-15). Most research has focused on SRC in adult male players. There are fewer studies on youth, in particular female youth. Further research into SRC in youth male and female players is thus required.

Aim: The aim of this study was to determine the incidence and mechanism of SRC among youth male and female rugby players at the 2011 to 2018 and 2015 to 2018 South African Rugby Union Youth Week Tournaments respectively.

Specific objectives: a) To determine the incidence of SRC among boys U13-U18 and girls U16-U18 players; b) To describe SRC mechanism of injury in boys U13-U18 and girls U16-U18 players; c) To determine if a difference in SRC incidence exists between boys U13-U18 and girls U16-U18 players, and also, between age groups; d) To determine if a difference in mechanism of SRC exists between boys U13-U18 and girls U16-U18 players, and also, whether the difference exists between age groups; and e) To describe l factors associated with SRC in boys U13-U18 and girls U16-U18 players.

Methods: The study had a retrospective, epidemiological design. The study reviewed SRC injury data collected at the 2011-2018 South African Rugby Union Youth Week Rugby Tournaments. SRC injury data for boys was collected at the 2011-2018 South African Rugby Union Youth Week Rugby Tournaments. SRC injury data for girls was collected only at the 2015-2018 South African Rugby Union Youth Week Rugby Tournaments, as the girl's tournaments were only introduced in 2015.

Results: Data from 266 SRC events were analysed in the study. Overall SRC incidence was 7.0 SRC per 1000 match playing hours (95% CI, 6.2.-7.8). Overall SRC incidence for boys was 6.9 SRC per 1000 match playing hours (95% CI, 6.0-7.8). Overall SRC incidence for girls was 7.9 SRC per 1000 match playing hours (95% CI, 5.3-9.9).

There was no significant difference in SRC incidence between boys and girls. SRC incidence from 2011-2018 was 10.7 (95% CI, 8.2-13.1), 7.5 (95% CI, 5.5-9.6) and 5.3 (95% CI, 3.4-6.5) SRC per 1000 match playing hours for boys U13, U16 and U18 age groups respectively. SRC incidence from 2015-2018 was 7.2 (95% CI, 3.7-10.2) and 7.9 (95% CI, 4.7-10.9) SRC per 1000 match playing hours for girls U16 and U18 age groups respectively.

There was a significantly higher incidence of SRC in the boys U13 age group when comparing boys U13 and U18 age groups (IRR 2.0; 95% CI, 1.5-2.7; p=0.00014). Boys U13 players were twice as likely to sustain a SRC than their U18 counterparts. The tackle (65%) and ruck (20%) were responsible for the majority of SRC. Boys U13 players were significantly more likely to sustain a SRC from a tackle than boys U18 players (p= 0.01). Boys U16 players had a significantly greater incidence of SRC resulting from the ruck than boys U18 players (p=0.02). Overall the most common primary mechanisms of SRC were front-on tackles (27%) and collisions (18%). Boys U16 players had a significantly higher rate of SRCs due to front-on tackles than boys U18 players (p=0.00007). U16 boy players also had a significantly higher rate of SRCs caused by collisions than U18 boy players (p=0.00007). Similarly, boys U13 players had significantly higher incidences of SRCs due to collision than boys U18 players (p=0.003). Factors that were associated with SRC incidence were tournament day and the use of headgear. SRC was more likely to occur on day two than day four (p=0.0008), day five (p=0.0002) and day six (p<0.001). Players who did not wear headgear were more likely to sustain a concussion than those who did (p<0.001).

Conclusion: Overall SRC incidence at the 2011 to 2018 South African Youth Week Rugby Tournaments was 7.0 SRC per 1000 match playing hours. This study is unique as it reports SRC incidence for youth female players. The overall SRC incidence for girls U16 and U18 groups was 7.7 SRC per 1000 match playing hours. As no significant difference was found for the incidence, injury event and mechanism of SRC between male and female players, similar injury prevention strategies can be implemented with these groups. Injury prevention strategies should focus on teaching safe contact technique in the tackle and ruck. Particular attention should be focused on teaching safe contact technique in U13 boys as the SRC incidence was highest in this group. Injury prevention strategies should also focus on teaching U13 and U16 boy players how to avoid collisions; and teaching U16 boy players how to execute safe front-on tackles and rucks. Further research should focus on identifying what aspects of the tackle and ruck result in SRC so more tailored and specific injury prevention strategies can be implemented.

Chapter One: Introduction and Scope of Thesis

Rugby Union (henceforth known as 'rugby') is a popular sport worldwide. In South Africa there are an estimated 418, 509 players (6). Rugby further enjoys immense popularity among the youth; and the number of players have increased in recent years, particularly among young girls (6). In 2017 a record number of 2, 1390, 300 young players were introduced to the game. Of these players 39% were girls (16). For the purposes of this thesis 'youth' players will henceforth refer to boys and girls playing in U13 to U18 age groups.

Due to the physical nature of rugby the incidence of injuries is high (17). Of these injuries, sport-related concussion (SRC) is one of the most common (18-20). SRC incidence in rugby is relatively high across all age groups. A recent systematic review reported an overall incidence rate of 4.7 SRC per 1000 match playing hours, across age levels (20). To date most SRC research has focused on adult male professional players; however, recently there has been increased focus on youth players. Previous studies have reported SRC incidences of between 0.2-1.8 SRC per 1000 match playing hours in male youth players (7, 20, 21). A study conducted in South Africa reported an even higher incidence of 5.8 SRC per 1000 match playing hours in male youth players at the 2011-2013 Craven Week Tournaments (22).

There is scant research on SRC in female rugby. An incidence of 0.3 (23) and 1.6 (24) SRC per 1000 match playing hours has been previously reported in adult, professional and collegiate female players respectively. Three previous studies have reported combined SRC incidence in male and female youth players (25-27), but to date no studies have reported SRC incidence exclusively in female youth rugby players.

Investigation into SRC among male and female youth rugby players is of great importance. Currently it is thought that youth athletes may be more vulnerable to developing SRC (7). Youth athletes are also thought to be at increased risk for certain SRC complications, in particular persistent post-concussive symptoms. Although not fatal, persistent post-concussive symptoms may severely impact on quality of life (9). Youth athletes also take longer to recover from a SRC than adults (28). Female athletes are further thought to be at a higher risk of developing SRC than their male counterparts (11). One study conducted among high school athletes found that female athletes were almost twice as likely to sustain a SRC than their male counterparts when participating in soccer, basketball and softball (12). Additionally, female athletes are also reported to take longer to recover from SRC, and are thought to be more prone to developing certain SRC complications than male athletes (13-15).

Recently several rugby injury prevention programmes have been developed. In South Africa the BokSmart rugby injury prevention course was introduced in 2009 with the main goal of reducing the number of catastrophic head, neck, and spine injuries. Preventing SRC is a key-focus of the programme. It is compulsory for all rugby coaches and referees to complete the course every two years (29, 30). According to Van Mechelen's injury prevention model it is crucial that incidence and mechanism of injury be identified for injury prevention strategies to be effective (31). According to Finch's more recent Translating Research into Injury Prevention Practice (TRIPP) model it is crucial that injury incidence, aetiology and mechanism of injury be comprehensively described before effective injury prevention strategies can be planned and implemented (32). However little research has focused on SRC in youth rugby (20); and to date no studies have exclusively investigated SRC in female youth rugby. No studies have been conducted investigated SRC incidence in South African female youth players. Due to the increased susceptibility of youth players (7) and in particular female players (13-15) to sustain SRC and develop SRC complications, further research into these groups is warranted. Through further research of SRC in male and female youth rugby, it can be ensured that injury prevention programmes such as the BokSmart programme are targeting the essential elements to prevent SRC in these vulnerable groups. Research will also contribute to the current evidence base regarding SRC in youth rugby. Increasing the youth rugby SRC evidence base may eventually contribute to rule changes in the game, which are designed to make it safer.

The next chapter will review the current literature on the epidemiology of rugby injuries and SRC, with a particular focus on injury and SRC incidence in male and female youth rugby players. The pathophysiology, signs and symptoms, recovery from SRC and possible complications of SRC will be discussed. SRC identification, evaluation, management and prevention, particularly with relevance to youth rugby, will also be discussed.

Data were sourced through searches of PubMed, Medline and Web of Science. Keywords used in the search included: *Sport-related concussion, Concussion, Rugby, Rugby Injuries, Concussion Physiology, Youth Rugby, Junior Rugby, Female Rugby, Women's Rugby, Girl's Rugby; Prevention of Concussion, Education Programmes, Injury Prevention; Concussion Identification, Concussion Evaluation, Concussion Management.* Additional information was gathered directly from the websites of World Rugby and the South African Rugby Union.

Chapter Two: Sport-related Concussion in Rugby – Review of the Literature

2.1 Rugby Injury Incidence

An Overview of Rugby Injuries

Rugby is a popular sport worldwide. It is played across 121 different countries by 8.5 million players (6). The number of youth players, particularly girls has increased recently. Rugby is a popular sport in South Africa, with an estimated 418,509 players (6).

Rugby is a sport characterised by frequent contact and collisions between players (21, 33). The incidence of injury in rugby is relatively high due to the physicality and high impact nature of the game (17, 28). There is no variation in the laws and rules of the game between male and female rugby (34). However, slight differences exist between youth and adult level rugby; namely variations in scrum laws and a reduction in the length of the youth game (1). Scrums laws vary in a number of ways. According to World Rugby it must be ensured that youth teams have appropriately trained players to engage in the scrum. If appropriately trained players are not available for whatever reason, an uncontested scrum with eight players a side must be awarded. Further if one team has to reduce their scrum to less than eight players the opposing team must do so to. The scrum may be reduced to a minimum of five players on each side.

Internationally, rugby is reported to have one of the highest injury incidences of all team sports. The injury incidence varies across both age groups and levels of competition. It has been well documented that injury incidence tends to increase as the player gets older and/or as the level of competition increases (35). This can be attributed to increases in player physical stature, competitiveness and aggression of players, game speed, foul play, and length of the rugby season (36, 37). It must be noted that the vast majority of rugby injury research has focused on adult male players (20, 38). Research among youth players is limited (39).

Research among female players is even more limited (34). Of the limited research that has been conducted on females, most has focused on the elite adult level of participation. The injury incidence in female rugby may be lower than that of male rugby (40). This is reflected by a study that investigated injuries in male and female New Zealand Rugby League players. The study showed that injuries to female players accounted for only 6% of all Rugby League injuries recorded over an eight year period (41). However, the lower number of female players compared to male players partially explains this finding. In addition, due to Rugby League having different rules to Rugby Union, the results cannot be applied directly to Rugby Union. Another study conducted over a five year period among college level male and female rugby union teams showed the incidence rate of injuries in men was 30% higher than that of females (42). A study conducted in New Zealand found that male players had a higher incidence of injuries than females (10.9 injuries and 6.1 injuries per 100 player games in males and females respectively) (43). Suggested reasons for injury incidence being higher in men's rugby includes: the increased size of players, increased speed of play, and increased aggressiveness of players (40). Additionally lower muscle power, peak aerobic capacity and higher skin fold measurements are also suggested as reasons why injury incidence among female players may be lower (41). The lower number of females participating in the game and thus the reduced competitiveness is also theorised as a reason why injury incidence in females is reported to be lower (43).

It is important to consider that reported rugby injury incidence is affected by the definition of injury and method of data collection. Before 2007, rugby injury studies used a variety of definitions and data collection methods which have limited the value of individual studies and the ability to compare these studies (20, 44). To improve study homogeneity and subsequent comparability the International Rugby Board, now known as World Rugby, published the Consensus Statement on Injury Definitions and Data Collection in Rugby in 2007. Guidelines suggest that studies should be designed as prospective cohort studies that follow more than one team over a minimum of one full season, year or major tournament.

The guidelines also provide definitions of rugby injuries to be utilised by researchers (44). The following definition of injury was accepted;

> *"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" (44).*

Youth Rugby Injuries

Injury incidence in youth rugby is relatively high. Concern over youth rugby injuries is so fraught that extreme measures such as banning the tackle in the youth game have been suggested (39). A recent systematic review reported an injury incidence of 26.7 injuries per 1000 match playing hours in male and female youth players (28). However, only three of the 35 included studies investigated rugby injury incidence in female players. Therefore, results among this group should be interpreted with caution. Similarly prospective injury surveillance studies conducted in Irish (8) and English (21) schools found incidences of 29.0 and 124.0 injuries per 1000 match playing hours respectively in these cohorts (8). Further, a recent large-scale prospective study conducted among Australian school boys reported an injury incidence of 23.7 injuries per 1000 playing hours (45). In South Africa a large prospective study conducted among 320 school rugby teams reported a much lower incidence of 7.0 injuries per 1000 match playing hours among school boys. The lower reported injury rate in this study can be attributed to underreporting of injuries and the methodology used in the study (46). Also, the study was published 20 years before World Rugby's consensus statement when the demands of the game were different. A study conducted at the 2011 South African Rugby Union Youth Week Tournaments found an over-all incidence of 23.1 time loss injuries per 1000 match playing hours in male youth players (36).

High injury incidence rates in youth rugby have been attributed to: possible mismatches in physical size between players (8), poor tackling technique, and inadequate physical conditioning (3, 21). Adolescents in particular may engage in more dangerous styles of play increasing their injury risk (8). Adolescents are further thought to be at increased risk for injury due to deficits of sensori-motor function that occur in relation to rapid growth spurts between the ages of 12 and 14 (47). Further research into the aetiology of injury in youth players is required so that effective injury prevention strategies can be implemented amongst this group (32).

Within youth rugby injury incidence tends to increase as players get older, and at more elite levels of youth rugby (8, 48). A study conducted at the South African Rugby Union Youth Week Tournaments found an incidence of as high as 47.9 injuries per 1000 match playing hours in male youth players (36). Another study found an injury incidence of 77.0 injuries per 1000 match playing hours among elite male adolescent English players (49). Higher injury incidence at elite levels of youth rugby is thought to be related to the increased physicality of the game and longer game time (21). Youth players of larger physical stature have also been shown to be at higher risk of sustaining an injury (8). This is worrying as many strength training and nutritional interventions aim at increasing young player's physical stature (8).

Despite the increasing number of young girls participating in rugby (16), the literature describing the incidence of rugby injuries in female youth players is scarce. This lack of research is concerning as the number of female players, particularly youth female players has increased in recent years (20). Only one study has reported injury incidence in female youth rugby players. This study, which was conducted in the United States of America, found an injury incidence of 4.1 injuries per 1000 playing hours (27). This is highly concerning as according to Finch (32) and Van Mechelen (31) understanding the extent of an injury amongst a certain group is the first step in planning future injury prevention strategies. ***.*** Further research amongst female youth rugby players is this required.

Adult Rugby Injuries

When considering youth rugby injuries, it is important to consider them within the broader picture of rugby injuries as a whole. Since the introduction of professionalism in 1995 rugby injury incidence has increased at professional and non-professional male adult levels of play (35, 50).

Of the few studies on non-professional male adult players, two studies reported an incidence of 52.0 injuries per 1000 match playing hours (51, 52). Roberts et al (53) reported an incidence rate of 17.0 injuries per 1000 match playing hours in non-professional male adult players; however only injuries that resulted in a time-loss of eight days were included in this study. The main risk factor identified in these non-professional adult players was less experience (defined by playing years). No study has been conducted specifically evaluating injury risk in non-professional adult female rugby players. However, a cross-sectional study conducted among adult American female players of varying levels of play (amateur players to national representatives) found an injury incidence of 14.0 injuries per 1000 match playing hours (34). It must be noted that this study was published in 2005, before the introduction of standardised injury definitions by World Rugby; therefore, the results should be interpreted with some caution.

Injury incidence is highest in adult male professional rugby. In male professional club or provincial rugby injury incidences of 55.0 – 91.0 injuries per 1000 match playing hours have been recorded (33, 37, 54). In international level male rugby, injury incidence has been reported as high as 252.0 injuries per 1000 playing hours. The injury incidence at the 2015 Men's Rugby World Cup was 91.0 injuries per 1000 match playing hours (55). High injury rates in professional levels of play should be interpreted with caution due to the likely improved identification of injury by medical staff associated with the teams (20). This could result in a high reported injury incidence compared to teams with less sophisticated medical support structures.

Injury data concerning professional level female players is limited. A study conducted at the 2006 Women's Rugby World Cup found an overall injury incidence of 38.0 injuries per 1000 match playing hours (23). Four years later at the same tournament the injury incidence was similar (35.5 injuries per 1000 match playing hours) (56). Another study conducted among the England women's rugby squad found a lower incidence of 3.6 injuries per 1000 match playing hours (40). This study was conducted before World Rugby's injury consensus document was released.

The same study conducted among the England Women's rugby squad found that an increased risk of injury was associated with increased body mass and age (40). However, as this study was only conducted among 35 players over one season, further research is required to confirm these findings.

Current research clearly demonstrates that injury incidence increases as players get older (35); however it thought that estimated injuries incidences in youth rugby may not be completely accurate (39). Several points may explain why this may not be accurate in youth rugby. Firstly, youth rugby is commonly played in settings where no medical staff are available; therefore injuries are less likely to be identified (39). This is particularly true in South Africa (57). Secondly, youth players often do not disclose injuries as they are fearful of missing out on the game (28). Lastly, a lack of research into youth rugby may also have resulted in an underestimation of reported injury incidence (39).

Understanding injury epidemiology is an important step in the continuum of injury prevention (31, 32). Most rugby injuries occur during matches, during the contact phases of play in both youth and adult rugby. Match injuries have been reported to contribute to 80-90% of all injuries in male rugby (35). According to the study conducted by Doyle and George (40) match injuries accounted for 67% of all injuries among the England women's national rugby squad over the 2001 to 2002 season (40). Most injuries (75%) were also attributed to contact incidents in the 2006 Women's Rugby World Cup (23).

Overall, the most common rugby injuries reported among male players include: lower limb and shoulder muscle and ligament injuries, SRCs, and head and face lacerations (35). Facial fractures are common in the adult male population; however, they are far less frequent among youth players (8). Severity of injury ranges from mild to severe, with more severe injuries tending to occur in older age groups and at higher levels of play in male rugby (35). The nature of injuries in female players are similar to injury patterns in adult male players. Most common injuries in female rugby include head/face, neck and knee injuries. The incidence of knee ligament injuries in female players is particularly high (40, 56). One study found an that the incidence of anterior-cruciate ligament injuries was 5.3 times more likely in female collegiate rugby players than male players (42).

The same study also reported that fractures and acromioclavicular joint injuries were more likely to occur in male players (42).

Rugby Injury Mechanisms and Factors Associated with Injury

Knowledge of the mechanism of injury is a crucial step in the injury prevention process (31, 32). Studies that provide detailed descriptions of mechanism of injury are needed to enable practical and effective injury prevention programmes to be developed. The tackle has been repeatedly identified as the contact event resulting in the most injuries in both adult and youth; and male and female rugby (3, 4, 33). Poor tackling technique has been recognised as one of the main injury risk factors in Under-18 (U18) elite level boy's rugby (58). Good tackling and contact technique is thus crucial to prevent injury (3). The risk of injury increases across all age levels from boys to adult male rugby.

Injury risk has also shown to be affected by the phase of the game. Risk of injury is higher in the second quarter compared to the first; and in the fourth quarter compared to the third. Further, it is recognised that injury risk is higher in the early part of the rugby season (35). This indicates that physical deconditioning and fatigue may be important contributing factors to developing an injury (37). It follows that physical fitness, good nutrition and hydration, and appropriate match recovery are important for reducing the risk of injury incidence in rugby (37). The research describing phases of the game and season where female players may be at higher risk for sustaining injuries is limited. One study suggests that injury risk may be higher in the second half of the game when compared to the first in elite female rugby (40). This study concluded player fatigue may be responsible for this finding (40). In contrast to this study, another study investigating female rugby injuries at the 2006 Women's Rugby World Cup found no significant difference in injuries in the first and second half of games respectively (23). Differences between the findings of these studies may be explained by the fact that the study conducted by Doyle et al (40) was conducted over one season and the other study was conducted over one tournament, the 2006 Women's Rugby World Cup.

Several studies have shown that previous injury may pre-dispose players to developing another injury. In particular, SRC has been shown to be one of these initiating injuries. A recent study by Cross et al (59) showed that adult male rugby players have a 60% higher risk of sustaining a time-loss injury when returning to play following a SRC in the same season. Another study of Irish school boys also showed that SRC may increase the risk of a subsequent injury. Studies investigating injury risk after SRC in other sports have similarly found increased risk of injury after return to sport post-SRC. For example two studies, on American collegiate athletes participating in a variety of different sporting codes found an increased lower extremity injury risk within the first 90 days after a SRC (60, 61). Brooks et al (61) found that collegiate athletes who sustained a SRC were almost 2.5 times more likely to sustain a lower extremity injury than those who had not. Herman et al (60) found an even higher risk of lower extremity injury post-SRC. This study found that athletes were over 3 times more likely to sustain a lower extremity injury after returning to sport post-SRC. Another study of 18216 high-school athletes across 27 different sporting codes showed that players had a 34% increased risk of sustaining a time-loss lower extremity injury after returning to sport (62).

Reasons for why injury risk may be increased after returning to sport following a SRC are unclear. Currently it is suggested that possible changes in neuromuscular control and cognitive deficits may be responsible. Neuromuscular control essentially refers to how the nervous system regulates postural control and muscle activation. At present it is suggested that full clinical recovery of a SRC takes approximately 7-10 days, however it is thought that subtle neuromuscular control and cognitive deficits, may persist well after full clinical recovery. These subtle changes may not be detected by current standard SRC testing (60, 61, 63). These small deficits could easily be exacerbated by the dynamic postural changes required; and cognitive challenges presented by the competitive sporting environment resulting in potential injury (63). Another potential reason explaining why athletes may be at increased risk for injury post SRC is that players who sustain a SRC may be more likely to engage in risk taking and aggressive playing styles predisposing them to developing SRC and other injuries. A recent study investigated SRC among 4961 athletes aged 15-35 years found that participants had an increased risk of injury before and after the SRC. Injury risk was not higher after the SRC suggesting that the increased risk of injury is related to the athletes playing style rather than the SRC itself (64). Evidence regarding why injury risk after SRC is increased is still in its infancy and further research is required. SRC is one of the most common rugby injuries (18-20, 35) and SRC may increase all-out injury risk (59), particularly lower extremity injury risk. It is thus warranted that SRC epidemiology be discussed further.

2.2 Rugby Sport-related Concussion Incidence

SRC is recognised as one of the most common rugby injuries (18-20, 35). It accounts for between 5-14% of all rugby injuries (33, 55, 65). A recent systematic review by Gardner et al (20) described an overall incidence of 4.7 SRC per 1000 match playing hours for adult male rugby; and an overall incidence of 0.6 SRC in both school boy and female rugby.

It must be noted that there is limited research on the SRC incidence in female rugby. One study reported a SRC injury density of 20.00 per athlete-season among Canadian university female players (13). In the 2006 IRB Women's World Cup a SRC incidence of 0.3 SRC per 1000 match playing hours were reported (23). Lastly there was an incidence of 1.6 SRC per 1000 match playing hours among American collegiate female players (24). Due to the lack of investigation into SRC among female rugby players, it is at present impossible to compare SRC rates between male and female players. The lack of research into female players is concerning as it has been identified by both van Mechelen (31) and Finch (32) that a solid evidence base describing injury incidence is required to develop injury prevention strategies.

The Berlin Consensus Statement on SRC in Sport, 2016 (66) describes SRC as a traumatic brain injury that causes a functional disturbance to the brain. SRC results from a biomechanical force applied to the brain. Forces may occur due to a direct blow to the head or from an indirect blow to another part of the body that transmits concussive forces to the brain. SRC does not cause structural disturbance of the brain and as such standard neuroimaging techniques will not display any abnormality (66, 67).

Typically, SRC causes rapid onset of clinical signs and symptoms associated with disturbed neurological functioning. It is however possible for signs and symptoms to be delayed for a number of hours. Signs and symptoms are divided into four categories (physical, cognitive, emotional and sleep) (18) and are presented in Table 2.2.1. A player does not need to lose consciousness to be diagnosed as having a SRC (66, 67). In fact only 10% of SRCs have concomitant loss of consciousness (68).

According to standard protocol, if a players presents with any of the signs and symptoms listed in Table 2.2.1, a SRC should be suspected and the player then should be immediately removed from play to undergo further evaluation (69).

Table 2.2.1: SRC Signs and Symptoms

Signs	**Symptoms**
Physical	Headache Dizziness Photophobia Phonophobia Blurred vision Nausea Numbness or tingling Vomiting Visual disturbances Balance deficits Loss of consciousness
Cognitive	Reduced concentration Memory deficits Feeling ‘foggy’ or ‘slowed down’
Emotional	Depression Irritability Rapid mood changes Increased aggression
Sleep	Drowsiness Insomnia Increased sleeping Difficulty sleeping

Note: From ‘Sports-related concussion relevant to the South African rugby environment’ by K. Patricios, R Kohler & R. Collins, 2010, *S Afr J Sports Med*, 22(4), p. 88.

SRC incidence varies across age groups and levels of play (20). According to the systematic review by Gardner et al (20) SRC incidence for male youth, adult community level and professional rugby is 0.6; 2.1 and 4.7 SRC per 1000 match playing hours respectively (20). However, it must be noted that several studies have suggested that SRC incidence may be significantly higher than what has previously been reported (7).

Underestimation of SRC incidence is thought to occur primarily due to underreporting of SRC by players and poor of identification of SRC by the coaching and medical support staff. This is particularly true among youth players (70). Underreporting of SRC by players occurs across all age groups and levels of play (19); mainly due to players having inadequate SRC knowledge and due to fear of being excluded from the current and subsequent games (19, 71). A study conducted among youth English male and female rugby players found that most players had a poor understanding of the signs and symptoms of SRC (72). Further, many youth and adult players admit that they have played while concussed or returned to play before they have been medically cleared (71, 73). One study conducted among Irish school boys found that only 30% of players would self-report a suspected SRC (70). Another study conducted among New Zealand high school rugby players found that most players have a poor understanding of SRC and return to play guidelines (74). A further study conducted among Australian community and school level rugby players showed that 100% of concussed players who received return to play advice failed to comply with return to play guidelines (75). Rates of underreporting have been suggested to be between 20-48% (19, 71, 74).

Other player reasons for not reporting SRCs include: being unaware that they were concussed; and thinking the SRC was not serious and a normal part of the game (76). Although only speculation, it is suggested that the inherently competitive rugby environment and pressure to continue playing further dissuades players from reporting SRC (19). Interestingly however, Delahunty et al (70) found that most players who continued to play, despite knowing they had a SRC did so due to internal motivation rather than external pressure from coaches and teammates.

SRC is also commonly not correctly identified, particularly at the youth levels of the game where appropriate medical staff are not always readily available (20, 70). SRC knowledge of player's parents has also been reported to be poor, therefore it is unlikely that parents of youth players would be able to identify a SRC in their child. One study found that 69% of primary caregivers were not aware of symptoms that may indicate SRC (77). However further research is required as another study conducted among parents of young rugby players found that parents generally had good SRC knowledge (78).

SRCs may also be missed because it is challenging to diagnose, even by a medical doctor (7) and because there is currently is no gold standard for the diagnosis of SRC (66, 67, 79). Similar to epidemiological injury studies, SRC studies are also limited by the use of inconsistent SRC definitions and data collection procedures (7, 20). World Rugby's consensus statement has attempted to amend this problem by (44); however the definition of SRC still remains problematic as the consensus statement does not provide specific criteria describing SRC. The most recent SRC definition is described by the Berlin Consensus Statement of SRC in Sport, 2016 (66). Unfortunately, this definition still does not provide researchers with clear cut clinical criteria to identify SRC. This may result in missed SRC or incorrect SRC diagnoses (67). Clear cut clinical criteria are yet to be defined due to the lack of gold standard criteria to diagnose SRC (66, 67, 79).

Sport-related Concussion Injury Mechanisms and Factors Associated with Sport-related Concussion

SRC occurs most frequently during matches, and most commonly during the contact phases of the game (20, 80). A recent study conducted among male, South African youth players at the 2011-2013 Craven Week Tournaments found that all incidences of SRC occurred during contact phases of the game (81). The tackle is further recognised as the contact event resulting in the most SRCs (80). The tackle accounts for 31% of all concussive injuries in elite male rugby (80). Similarly, the tackle was responsible for 44% of all concussive events at the 2011-2013 boy's U18 Craven Week Tournaments in South Africa. Further another study showed that the tackle was responsible for 62% of all SRCs in the 2011-2014 boy's South African Rugby Union Youth Week Tournaments (82).

Another study that attempted to identify SRC mechanisms in female rugby players from the ages of five to 19 years found that 52% of concussive injuries occurred when a player was tackling another player, or being tackled themselves (83).

Conflicting evidence exists concerning whether the ball-carrier or tackler is at a higher risk for sustaining a SRC. Currently it is suggested that the tackler may be at higher risk, though further investigation is required (84). A study conducted during the 2011-2014 boy's South African Youth Week Tournaments found a four-fold increased risk of sustaining a SRC in the tackler compared to the ball-carrier. Thus risk may be higher for the tackler in male youth rugby (82). There is also debate on whether forwards or backline players are more likely to sustain a SRC. Currently evidence indicates that SRC occurs equally among both groups of players (20). To date most studies on risk factors for sustaining a SRC have been conducted among adult male players. There is only one study on youth male players. This study was conducted at the 2011-2014 South African Rugby Union Youth Week Tournaments and showed that the hooker and loose-forward (both forwards positions) are at a higher risk of SRC than other positions (82). Further research into this group is warranted (7).

Similar to youth rugby SRC literature, the research on risk factors for SRC in female and girl's rugby is limited. In female Rugby League the number eight prop (a forward position) was the player exposed to the highest number of head impacts during games. The study however does not record how many of these impacts resulted in a SRC, therefore it is impossible to determine if the prop actually experienced a higher rate of SRCs than other positions (85). As explained earlier, the different rules governing Rugby League and Rugby Union make it difficult to translate findings from Rugby League to Rugby Union.

As the tackle is recognised as the contact event resulting in the most SRC, there has been increased focus on identifying aspects of the tackle that may increase risk of sustaining a SRC for the tackler and ball-carrier. Several novel studies using video analysis, have identified specific aspects of the tackle that may be associated with injuries including SRC in youth rugby. These factors will be discussed further when tackling technique is discussed below in '*Prevention of Sport-related Concussion'* section.

Similar to broader rugby injury research it has been shown that SRC is more likely to occur in the later phases of the game, particularly in the third and fourth quarters (82). These findings have been shown in males in both adult and youth rugby. This is thought to occur due to increased player fatigue (81, 82, 84). Other potential SRC risk factors include poor contact technique (82) and a previous SRC (86). Future research should focus on identifying specific mechanisms of injury and further describing SRC aetiology to ensure that research can be integrated into practical SRC prevention strategies. According to Finch (32) research into the aetiology of injury needs to be multi-disciplinary including biomechanical and behavioural to fully understand the multi-faceted nature of how an injury develops. SRC research thus needs to move away from purely describing injury incidence and basic mechanisms of injury, and start identifying the specific biomechanical and behavioural factors leading to SRC.

Sport-related Concussion in Youth Rugby Players

The incidence of SRC in youth rugby is higher than that of any other youth contact sport (87). A recent systematic review reported an incidence of 0.2-6.9 SRC per 1000 match playing hours in male and female youth rugby players (7). It should be noted however that this systematic review only included three studies that evaluated SRC in female youth players, out of the 25 reviewed studies. All three of these studies only reported combined SRC incidence in youth male and female players, and their samples included very few female players (25-27). Another recent systematic review reported an incidence of 0.2-10.7 SRC per 1000 match playing hours at school boy level rugby (20). Both systematic reviews included studies conducted in Australia, New Zealand, South Africa, the United Kingdom and the United States of America (7, 20). The study by Kirkwood et al (7) also included one study from Canada. A study conducted at the South African Craven Week Tournaments (2011-2013) reported an incidence of 5.8 SRC per 1000 match playing hours in youth male players (22). An incidence of 6.8 SRC per 1000 match playing hours was reported at the 2011-2014 boy's South African Rugby Union Youth Week Tournaments (82).

Literature describing SRC in youth female rugby players is scarce. In South Africa no studies have been conducted evaluating SRC incidence among youth female players. One study conducted among American high school rugby players found that SRC accounted for 14.3% of injuries among female players (27). The study however did not describe the incidence of SRC in this group. SRC has been investigated in females, in other sports.

A study among high school female athletes competing in soccer and basketball have recorded SRC incidences of 2.5 and 2.4 SRC per 1000 players respectively. These SRC rates were 1.9 times higher than the SRC rates recorded by the same study among high school male athletes in soccer and basketball (12). The paucity of SRC research in youth female rugby players makes the adoption of effective SRC injury prevention protocols difficult in this group. Injury prevention strategies cannot be effective, or proved to be effective when the extent of the injury is unknown in a certain group (31, 32).

It has been suggested that children and adolescents may be more vulnerable to developing SRC than older players (7). Factors associated with this include: reduced skull thickness, decreased neural myelination, greater head to body ratio, reduced neck muscle strength, and the increased vulnerability of a developing brain (68, 88, 89). Further younger players often have poorer contact technique resulting in an increased risk of sustaining a SRC (81).

The high incidence of SRC in youth rugby players is concerning as children and adolescents recover slower from SRC than adults and may have higher rates of certain SRC complications. Further research into the epidemiology of SRC in youth sports is thus warranted (28). Further research into this group will allow the development of effective SRC prevention strategies. It is further important that research moves past simply describing injury incidence (32). Studies investigating injury aetiology and investigating the effectiveness of injury prevention programmes are required (32).

Sport-related Concussion in Female Rugby Players

It is also been suggested that there are biomechanical reasons for female athletes being more vulnerable to developing SRC than their male counterparts (11). Biomechanical explanations include: lower head to ball ratio, weaker neck muscles, lower head/neck ratio with increased head mass in comparison to males resulting in increased linear acceleration of the head, and increased angular acceleration of the head and neck (14). Hormonal explanations have also been suggested. Hormonal explanations centre on the premise that oestrogen may have a detrimental effect to brain injury in females, but a neuroprotective effect in males (15). This has been demonstrated in animal studies where inducing brain injury after administering oestrogen had a neuroprotective effect in male rats and detrimental effect in female rats respectively (15).

Differences in neuroanatomy and physiology have also been proposed to explain why females seem more vulnerable to developing SRC than males. Females also have a greater number of unmyelinated neuronal processes which may make them more susceptible to developing SRC (12). Females also have a higher cerebral blood flow and basal rate of glucose metabolism which may exacerbate the metabolic cascade that ultimately results in the symptoms of SRC (12). The metabolic cascade will be further discussed in the *'Sport-related Concussion Pathophysiology'* section below.

Lastly, it is also thought that females are more likely to report SRCs than males. In the general population it has been frequently shown that females are more likely to report illness symptoms than men (90); it thus stands to reason that females may be more likely to report SRCs and its related symptoms (12). This is supported by a study conducted among collegiate athletes that showed females were twice as likely to disclose SRC than men (91). Also, a study conducted among American collegiate athletes found that females were more likely to report concussive symptoms than males (92). Females have also been found to have greater SRC knowledge than their male counterparts (93). Therefore, it most likely that increased SRC incidence reported in females is not just attributed to physical and physiological differences, but also to attitude and behaviour.

Several studies have shown that females often experience more severe SRC symptoms and a slower recovery period than males (11, 90). Female athletes may also have a higher risk of developing SRC complications than their male counterparts (13-15). One study specifically suggests that SRC recovery is slower in female teenage athletes than male teenage athletes (94). It is suggested that various physiological, hormonal, neurodevelopmental, muscular (particularly neck strength), and neuroanatomical differences between males and females result in the increased severity of SRC and subsequent symptoms in females (90, 94). Thus, because there is little literature regarding SRC in female rugby; and due to the fact that it is thought that females are more vulnerable to SRC, take longer to recover from SRCs, and are more susceptible to certain SRC complications, further research among this population is warranted. With further research more tailored injury prevention programmes can be designed for this vulnerable group.

Sport-related Concussion in Adult Rugby Players

As is discussed in the *'Rugby Injuries'* section above it is important to consider youth rugby injuries in the context of injuries among other age groups. SRC in adult male community level rugby players ranges from 1.2-6.9 SRC per 1000 match playing hours (20). Gardner et al (20) has suggested that the risk of SRC at this level may be the highest; however further investigation is required as very few studies have looked at SRC incidence in this group (84). In his 2014 systematic review Gardner further reported a SRC incidence of 0.3-7.8 SRC per 1000 match playing hours in male professional rugby (20).More recent prospective studies of professional adult male players have found higher incidences of 13.8 SRC per 1000 match playing hours (95) and 8.9 (59) SRC per 1000 match playing hours. This increase in incidence is attributed to an increased awareness and therefore increased reporting rate of SRC since the introduction of a formalised match Head Injury Assessment Protocol by World Rugby in 2012; as well as due to the increased focus of the popular media on SRC in recent years (59, 95). To date evidence suggests that SRC in youth rugby is lower than that of adult rugby. However, as youth players are at a higher risk of prolonged recovery and certain SRC complications further research in this group is warranted.

To fully understand SRC and SRC risks, pathophysiology and possible complications must be explored.

2.3 Sport-related Concussion Pathophysiology

The precise physiological mechanism of SRC remains unknown; however a similar physiological mechanism to what occurs in more severe brain injuries is thought to be responsible (96). In accordance with this mechanism, following a concussive blow there is an indiscriminate release of excitatory neurotransmitters and uncontrolled ionic influxes occurs in the brain. The main neurotransmitter involved is glutamate. The increased release of excitatory neurotransmitters results in an increased neurotransmitter binding to N-Methyl-D-Asparate receptors. This subsequently results in depolarisation of the brain's neurones as calcium and potassium ions are released (18, 96) (18, 89). This ionic shift leads to both acute and subacute physiological changes in brain's neuronal cells. The brain attempts to restore normal neuronal membrane potential by increased activation of the Sodium-Potassium-ATPase pump.

Increased Adenosine Tri-Phosphate is required to power the Sodium-Potassium-ATPase pumps, thus brain glucose metabolism increases (18, 89) (18, 96). Cerebral blood flow however is inadequate to meet the increased metabolic requirements of the brain. Thus, a mismatch between glucose supply and demand is created, resulting in cellular energy crisis. It is thought that the cellular energy mismatch is responsible for the rapid progression of signs and symptoms associated with a SRC, as well as other possible longer-term deficits and complications (18, 96) .

2.4 Recovery from Sport-related Concussion

The resolution of SRC signs and symptoms usually follows a typical sequential course. Full clinical recovery usually takes between 10-14 days (66); although recovery in children and adolescents may take longer (7). Clinical recovery refers to the time it takes for signs and symptoms of SRC to resolve (66). However recent evidence suggests that full physiological recovery lags behind clinical recovery. Physiological recovery refers to the time it takes for all physiological changes that occur in the brain to return to normal. Although not yet definitive it is suggested that full physiological recovery may take between 15-30 days. Currently it is unclear whether players are still at risk for complications in the physiological recovery period (97).

It is further suggested that females take longer than males to recover from SRC. Females are also commonly reported to experience more SRC related symptoms than males (98). Neurobehavioral and somatic symptoms are suggested to be particularly high in females recovering from SRC (98). Symptoms experienced more frequently by females include: headache, drowsiness, difficulty concentrating, increased emotionality, and increased irritability and sadness (15). There is also evidence to suggest females have 1.7 times the neurocognitive impairment post-SRC than males (15). A study conducted among 579 athletes (ages 11-20) found that males took an average of 23 days to return to play following SRC, whereas females took an average of 30 days to return to play (98). Another study found that it took female athletes 75 days and male athletes 45 days to recover completely from SRC. This is particularly worrying as currently a stand down period of only two weeks is suggested by the South African Rugby Union before a player may begin the graduated-return-to-sport protocol (99).

A number of reasons explaining why females take longer to recover from SRC than males have been theorised, but to date none have been empirically tested. Firstly, some symptoms are perhaps higher in females because these symptoms are more likely to occur in females with or without a SRC (13) For example, migraine type headaches which are associated with SRC are higher in females than males (15). Females also report higher rates of depression than males. This could explain why females report increased feelings of sadness post-SRC (15). Secondly, SRCs experienced by females may result in more severe SRC symptoms (11, 90). The more severe SRC symptoms are thought to occur due to biomechanical, anatomical, physiological and hormonal differences between males and females. These differences are discussed comprehensively in the earlier section *'Sport-related Concussion in Rugby'*. Thirdly, it is thought that females are more likely to report SRC symptoms than males. This is aligned to the finding that females are more likely to report illness symptoms than men (12). Thus the increased symptoms and recovery time in females may be at least in part due to a lack of symptom reporting by male athletes (15).

When a SRC symptoms last for longer than the expected clinical recovery time of a SRC they are referred to as persistent post-concussive symptoms. Symptoms are classified as persistent if they last longer than 10-14 days in adults and four weeks in children (9, 66). Persistent post-concussive symptoms are non-specific to SRC and may include: headache, anxiety, fatigue, dizziness and difficulty sleeping and concentrating (9). Deficits may persist for number of days, weeks, months or even years (18). It is currently unclear if persistent post-concussive symptoms represent continued physiological disturbance of the brain. Although not fatal, persistent post-concussive symptoms can significantly affect a player's quality of life. Persistent symptoms also pose a substantial management challenge to the medical staff involved (9).

Research into persistent post-concussive symptoms has been limited by a lack of a concrete definition of persistent post-concussive symptoms and the general low methodological quality of studies (9). Although further research is needed, it is currently suggested that persistent post-concussive symptoms may be linked to other co-existing or confounding conditions. Psychiatric co-morbidity in particular is high in those presenting with persistent post-concussive symptoms. It is thought that persistent symptoms may also be associated with returning to play too early (18). The most important predictor of developing persistent symptoms is the severity of the signs and symptoms immediately after and in the first few days following the concussive injury (66).

Having several signs and symptoms, a prolonged headache, migraine type symptoms, and memory loss after a SRC have been associated with an increased incidence of persistent symptoms. There is evidence that teenagers have the highest risk of developing persistent post-concussive symptoms (100, 101). Females have also been shown to have a higher chance of experiencing prolonged SRC symptoms than males (15).

2.5 Sports-Related Concussion Complications

It is crucial that all concussed players be identified and managed appropriately to ensure their safety (102) . SRC complications are possible. This is particularly true if a SRC is not identified and managed appropriately (68, 69). Complications include early and late complications and are presented in the Table 2.3.1

Table 2.3.1: SRC Complications

Early complications	**Late complications**
• Intracranial space occupying lesions: epidural, subdural, and intra-cerebral haematoma • Second impact syndrome • Impact convulsions	• Neurodegenerative disorders including chronic traumatic encephalopathy • Increased risk for subsequent SRC

Note: Adapted from 'Sports-related concussion relevant to the South African rugby environment' by K. Patricios, R Kohler & R. Collins, 2010, *S Afr J Sports Med*, 22(4), p. 88.

Intracranial space occupying lesions and second impact syndrome are both potentially fatal SRC complications. It is thus crucial to understand and be able to recognise these conditions (7, 18).

Although not a direct complication of SRC it is important to consider intracranial space occupying lesions while assessing a potentially concussed player as it is often difficult to distinguish space occupying lesions from a SRC, particularly in the initial clinical presentation (18).

A space occupying lesion involves damage of cerebral blood vessels. Space occupying lesions are classified as epidural, subdural or intracerebral haematomas. Bleeding from damaged blood vessels in the brain causes an increase in intra-cranial pressure that may be fatal if recognised immediately and managed appropriately (18). It is thus crucial that all players are monitored for signs of raised intra-cranial pressure for the first 48-72 hours after the injury (18).

Second impact syndrome is a potentially fatal condition that occurs due to cerebral oedema and loss of the brain's ability to auto-regulate blood flow. Second impact syndrome is more common in children and adolescents (18, 68). There is currently debate about the aetiology of second impact syndrome. One school of thought theorises that second impact syndrome occurs when a player receives a second concussive impact before an initial SRC is resolved. In contrast, other experts suggest that second impact syndrome represents a separate malignant pathophysiological brain oedema that has nothing to do with the 'second impact' (103).

Impact convulsions are another potential early complication of SRC. However, in contrast to intracranial space occupying lesions, impact convulsions are usually benign in nature. They do however cause considerable distress to observing coaches, spectators and players (18, 104).

In recent years concerns regarding a possible increased incidence of neurodegenerative disorders in athletes that have sustained repetitive head impacts and SRCs throughout their careers has grown (105-108).

Chronic traumatic encephalopathy in particular has incurred considerable media interest (109). Chronic traumatic encephalopathy is thought to occur due to brain damage resulting from cerebral deposition of a specific protein called the tau protein. The protein deposition and subsequent brain damage is thought to occur due to repetitive concussive and sub-concussive blows. Chronic traumatic encephalopathy may result in depression, disinhibition and cognitive dysfunction among other symptoms (105). Although chronic traumatic encephalopathy has been confirmed in several former National Football League players; to date only one confirmed case of chronic traumatic encephalopathy in a retired rugby player has been reported (106).

Further research is thus required to determine rugby players' risk of developing chronic traumatic encephalopathy (106, 107). Future research is also required to determine a cause-effect relationship between repetitive head impacts or SRCs sustained in contact sports and chronic traumatic encephalopathy (108).

Other long-term consequences thought to be associated with repetitive SRC include: depression and mild cognitive disorder (108, 110). Just as with chronic traumatic encephalopathy, there is insufficient evidence about SRC to determine a cause-effect relationship, and well-designed prospective studies are required (106, 108, 110, 111). To date most long-term studies have not adequately accounted for potential third variables (108). Prospective long-term studies of rugby player brain health have also been suggested (112). Another deficiency in the knowledge about chronic traumatic encephalopathy and other long-term consequences of SRC, is that most of the studies have used male athletes. This is concerning because there is a higher reported incidence of SRC in females compared to males (91). Research into these complications among female athletes is thus imperative.

Lastly a previous SRC may increase the risk for sustaining a subsequent SRC (101). This follows from a recent prospective study (59) which showed that sustaining a SRC increased players risk for subsequent time-loss injury in the same season by 60% (59).This needs to be investigated further as an increased risk of SRC may rather be associated with an aggressive playing style or more playing exposure (18).

Summary of Injuries and Sport-related Concussion in Rugby

Rugby injury incidence is high across all levels and ages of play (17, 28) . Knowledge of injury incidence and mechanism of injury is important to develop injury prevention programmes (31, 32). Injuries seem to be lower in female rugby, but this finding is based on few studies. Incidence and severity of injuries tends to increase with increasing levels and ages of play (35) . The vast majority of injuries occur during matches and the tackle is recognised as the contact event resulting in the most injuries (3, 4, 33, 35).

SRC is one of the most common rugby injures. SRC has a high incidence across age groups and levels of play (20). SRC investigation among youth and adult female rugby players is limited and requires further research, particularly since the number of players has increased. As knowledge of SRC incidence and aetiology is essential for the development of effective injury prevention strategies (31, 32), it is crucial that further research investigate SRC in these vulnerable groups. Research into other sports has shown that SRC incidence in females may be higher than their male counterparts (12). Despite the high incidence it is still thought that current SRC incidence is underestimated primarily due to underreporting by players (20). This is particularly true in youth players. SRC occurs most commonly in matches during the tackle (80). SRC in youth players is thought to occur less frequently than in adult players. However further information about SRC in youth is important because youth are suggested to be more susceptible to SRC, recover more slowly from SRC, and may be more susceptible to certain SRC complications (28).

SRC results in a complex pathophysiological process that causes a functional disturbance to the brain. A number of signs and symptoms are possible. The presence of any of these should result in the player immediately being removed from the game (66, 69). Life threatening complications such as intracranial space-occupying lesions are possible (68, 69).. Although chronic traumatic encephalopathy has garnered considerable attention in recent years, further study is required to ascertain its prevalence in rugby players (106, 107) and clarify its association with SRC. SRC symptoms may also become persistent, as occurs with persistent post-concussive symptoms. Persistent post-concussive symptoms can have significant impact on quality of life. (9, 18, 66).

It is imperative that the SRC be appropriately and timeously identified to prevent possible SRC complications and ensure optimal management of the SRC. It is also crucial that the player then be managed appropriately (66, 102). An in-depth exploration into the identification and management of SRC is thus warranted.

2.3 Identifying and Managing the Concussed Player

Appropriate identification and subsequent management of the concussed player is crucial to ensure player safety, health and welfare (66, 102). Worldwide the evaluation and management of SRC in rugby is governed by legislation set by World Rugby. SRC evaluation and management in South Africa is further regulated by the South African Rugby Union (99). Currently few differences exist in the identification and management of SRC between youth and adults. Further no differences exist in the identification and management of SRC between male and female athletes (75).

On-field Sport-related Concussion Evaluation and Management

The concussed player should be recognised and removed from play to ensure their safety (66). The first responder should first address basic aspects of first aid including cervical spine protection and airway, breathing, and circulation evaluation and management. Cervical spine protection is particularly important if the player presents with confusion, loss of consciousness, and signs of cervical injury (18).

Once basic first aid priorities have been addressed the first responder should then evaluate if any signs and symptoms of SRC exist. Ideally play should be stopped while the injured player is assessed (18). In cases where there are no overt SRC signs and symptoms, a brief neuro-psychological test should be administered to assess recent memory. It is recommended that Maddock's questions be utilised for this purpose (18). Maddock's questions are further described in Table 2.3.4. It is important to note that standard orientation questions (time, place and person) are not valid for the assessment of SRC (113).

SRC identification tools such as the Concussion Recognition Tool 5 (Figure 2.3.1) should be used by non-medical personnel to accurately identify and manage SRC. The tool includes common signs and symptoms of SRC, Maddock's questions, and advice on how to manage the suspected SRC. The Concussion Recognition Tool 5 is useful to ensure that no SRCs are missed due to a lack of medical staff present. It is crucial to note however that the Concussion Recognition Tool 5 does not diagnose SRC. The player must still be assessed fully by a doctor to be diagnosed with SRC.

Lastly although use of the Concussion Recognition Tool 5 is recommended, research evaluating its efficacy in the identification and management of SRC is lacking (114).

Figure 2.3.1: Concussion Recognition Tool 5 (114)

According to current South African Rugby Union legislation any player with a suspected SRC should be promptly removed from play for further assessment (99). A SRC should be suspected if a player presents with any signs and symptoms of SRC (66, 69). Once a player has been removed from the field for SRC evaluation he/she may not return to play on that day whether or not a SRC is diagnosed (66). An exception to this rule occurs at the elite adult level of rugby where according to the World Rugby's Head Injury Assessment Protocol a player may be returned to play if a SRC is not diagnosed by the team doctor in side-line evaluation (115, 116) . No player with a diagnosed SRC may return to play on the same day (66).

Side-line Evaluation and Management

Side-line evaluation should be performed by a doctor in a quiet medical room. The evaluation should be performed as soon as possible. Side-line evaluation is used to: confirm the SRC diagnosis, establish a baseline of symptoms, and to determine if referral to hospital is required. At minimum side-line evaluation should include: assessment of SRC symptoms, evaluation of cranial nerve and cognitive function, and balance assessment (66). No gold standard exists for the side-line diagnosis of SRC (117); however it is recommended that the doctor uses the Sport Concussion Assessment Tool for evaluation (102). The most recent version of the Sport Concussion Assessment Tool is the Sport Concussion Assessment Tool 5 (SCAT5) (66). The SCAT5 is arguably the most effective SRC evaluation tool available. It includes several SRC evaluation tools presented in a logical and easy to use fashion. An adult and child version of the tool exists (79). The child version of the Sport Concussion Assessment Tool was designed for use in players under the age of 13 (118). Although the SCAT5 assists the doctor in making a diagnosis of SRC, the decision is ultimately one of clinical judgement (79).

If the player is diagnosed with a SRC the doctor must decide if hospital referral is necessary, or if the patient can be appropriately managed at home. A concussed player should be sent home with a responsible adult who is able to monitor the player over the preceding 48 hours. The player and his caretaker should be educated and given written instructions on the “Do’s and Don’ts” of acute SRC management and possible reasons to contact their nearest emergency medical centre (18). Relevant information is summarised in Table 2.3.2. No player with a diagnosed SRC should be allowed to return to play on the same day (66).

Table 2.3.2: Home SRC Management

Do's	**Don'ts**	**Contact Emergency Department if:**
• Monitor SRC signs and symptoms • Complete physical and cognitive rest- no exercise; no schoolwork; no television, cell phone or computer usage • Sleep as necessary • Avoid noisy environments and excessive light	• Do not drive • Do not consume alcohol • Do not take large quantities of painkillers or sleeping pills- follow the doctor's instructions	• Deterioration of signs and symptoms • Headache severity increases significantly and does not respond to simple pain killers (e.g. paracetamol) • You have a seizure • You experience extreme irritability, visual or balance problems • You or anyone else has concerns about your condition

Note: From 'Sports-related concussion relevant to the South African rugby environment' by K. Patricios, R Kohler & R. Collins, 2010, *S Afr J Sports Med*, 22(4), p. 88.

Hospital Referral

Appropriate hospital referral is important for player's health and welfare. Referral to hospital is usually only indicated if an intracranial lesion is suspected (18). Indications for hospital referral are summarised in Table 2.3.3.

Table 2.3.3: Indications for immediate hospital referral

Hospital referral indications
• Skull fracture • Penetrating skull trauma • Deterioration in consciousness post injury • Focal neurological signs • Confusion/impaired consciousness >30 min • Loss of consciousness >5 min • Persistent vomiting and worsening headache post injury • Convulsions • >1 concussive incident in the match/training session • Difficulty in assessing (e.g. intoxicated patient) • All children with head injuries

Note: From 'Sports-related concussion relevant to the South African rugby environment' by K. Patricios, R Kohler & R. Collins, 2010, *S Afr J Sports Med*, 22(4), p. 88.

Follow-up Sport-related Concussion Evaluation and Management

The follow-up consultation must be performed by a doctor; preferably by a sports physician, neurologist or neurosurgeon with experience in SRC (18). All follow-up consultations should include a thorough medical history and neurological examination. Examination must include assessment of: cognitive, ocular and vestibular function, mental status, gait and balance deficits, and sleep/wake disturbances. The doctor must determine if the player's clinical status has improved or deteriorated. Also, the doctor must determine if a more severe brain injury has occurred and refer for neuroimaging as appropriate (18, 66). The SCAT5 may be used for follow-up consultations; however, it is only valid for use in the first three to five days following a SRC (66). Symptom checklists are considered the most useful tests in tracking clinical recovery (66); although management decisions are ultimately one of clinical judgement.

Neuro-psychological testing may also be performed to assist in management decisions. However, neuro-psychological testing should never be used as the only SRC assessment test (18, 66, 68). Neuro-psychological testing involves paper based or computerised tests that are used to evaluate cognitive function. Neuro-psychological testing will be discussed further below and in Table 2.3.4. The primary management of SRC includes cognitive and physical rest until symptoms resolve. Complete rest is only advocated for the first 24-48 hours. The exact amount of rest required is yet to be defined (66, 119). After an initial period of rest, players should be encouraged to gradually increase non-sporting activities (119). Children and adolescents usually require no longer than two to five days break from school (120). It is however important to note that research into SRC management in children and adolescents has been extremely limited and further research into management of SRC in adolescents and children is indicated (66).

Although rest and a gradual increase in activity is the mainstay of current SRC treatment, evidence is emerging that suggests that a more active approach to treatment may yield better results. Vestibular therapy and physiotherapy management of the cervical injuries, cognitive behavioural therapy and the use of sub-maximal exercise that does not aggravate symptoms have shown to be effective in managing SRC related symptoms (119). Usually no pharmacological treatment is required; however, in some cases symptomatic treatment is indicated. Pharmacotherapy may include: mild analgesics such as paracetamol for headaches; anti-emetics for nausea, anti-vertigo agents for prolonged nausea, hypnotics for insomnia, selective serotonin reuptake inhibiters for affective disorders, and neuro-stimulants for cognitive or attention deficits (69). Although pharmacological management may help manage the symptoms of SRC, there is no evidence that it has any effect on the SRC itself (119). Treatment for individuals with persistent post-concussive symptoms is similar to management of an acute SRC; however, there is no evidence for the use of pharmaceuticals in the treatment of persistent post-concussive symptoms (9).

Once the player has demonstrated complete clinical and cognitive recovery, he/she may begin the graduated-return-to-sport protocol. Neuro-psychological testing may assist the doctor in making return to play decisions but ultimately the judgement is a clinical one (68). Currently it is unclear if a player is safe to return to full play following complete clinical recovery or if they are only safe to return after full physiological recovery. Research in the area is limited by a lack of longitudinal studies following players until full physiological recovery (97).

Further research is required to solve this dilemma (121). Current research also suggests that the doctor should take sex into account when making return to play decisions, as current evidence indicates that females take longer to full recover from SRC than males (12).

According to World Rugby and the South African Rugby Union, adults who sustain a SRC may begin the graduated-return-to-sport protocol a minimum a week after the SRC, and players 18 years and under may begin the graduated-return-to-sport protocol a minimum of two weeks after the SRC (99). Only adults who have access to an 'advanced level of SRC care' as defined by the World Rugby may be considered for an earlier start of the graduated-return-to-sport protocol (99). Only a doctor may decide if a player is ready to begin the graduated-return-to-sport. The graduated-return-to-sport protocol is a five-stage rehabilitation protocol that the player must progress through to be allowed to return to play. The player progresses through each stage with 24 hours separating stages. The player must remain symptom free to be allowed to progress to the next stage. If symptoms flare up the player is dropped to the previous stage, where he or she must remain for a further 24 hours before they are permitted to progress. Thus, the graduated-return-to-sport protocol will take athletes a minimum of four days to complete. The graduated-return-to-sport protocol is summarised in Table 2.3.4. Although it is recommended that the graduated-return-to-sport protocol be supervised by a doctor, another appropriately qualified medical professional that knows the player well may supervise the protocol if this is not possible (18, 66, 69).

Table 2.3.4: Graduated-return-to-sport protocol

Rehabilitation Stage	Functional Activity	Objective
1. No activity	Physical and cognitive rest	Recovery
2. Light aerobic exercise	Light aerobic exercise: • Jogging, stationery cycling, swimming • No resistance training	Increase heart rate
3. Sports specific exercise	Rugby specific running drills and movement patterns: • No potential head impact activities	Add movement
4. Non-contact drills	More complex rugby drills including passing ball: • Still no contact • May add resistance training	Challenge co-ordination and cognition
5. Full contact practice	Normal training	Restore confidence and assess functional skills
6. Return to game	Return to matches	

Note: From 'Consensus statement on concussion in sport- the 5th international conference on concussion in sport held in Berlin, October 2016' by P. McCrory et al, 2017, *Br J Sports Med*, 0, p. 3.

Sport-related Concussion Evaluation Tests

SRC evaluation tests include side-line tests, and other tests used to monitor the symptoms of SRC and assist in making decisions about return to play. Side-line tests are divided into five groups including: symptom and clinical sign scales, balance tests, oculomotor tests, cognitive tests and multimodal assessment tools (102). Tests used to monitor SRC include symptom checklists (66) and neuro-psychological testing (18, 66, 68).

The use of technology such as head impact sensors and side-line video analysis of head impact mechanism has also been used in recent years in an attempt to improve SRC identification (66). Multi-time head injury assessment protocols such as World Rugby's Head Injury Assessment Protocol have also been implemented to assist in SRC identification (115). Common tests listed above are further described in Table 2.3.5.

Table 2.3.5: SRC evaluation tests

SRC Evaluation Tool	Use & Description	Test Type
Maddock's questions	Set of sport-specific orientation questions used to assess attention and memory (57).	Cognitive (102).
Graded symptom checklist	22-point symptom checklist that subjectively assesses the player's SRC related symptoms (46).	Clinical symptoms and signs (102).
Standardised assessment of SRC	Cognitive evaluation that assesses player orientation, delayed recall, and digit and month's span (63).	Cognitive (102).
Modified balance error scoring system	Quick side-line assessment of postural stability on a stable surface (firm ground) (46).	Balance (102).
Balance error scoring system	Quick side-line assessment of postural stability on a stable surface (firm ground) and unstable surface (foam pad) (62).	Balance (102).
King-Devik Test	Player reads a series of single-digit numbers aloud from left to right. Three cards are read as quickly as possible. Number of errors and time taken to complete the test are recorded. Baseline testing is performed (66).	Oculomotor (102).
Neuro-psychological testing (Paper)	Paper based test battery interpreted by a neuro-psychologist used to identify and monitor cognitive impairment post-SRC (18, 66, 68). Baseline testing may or may not be performed (61).	Cognitive (102).
Neuro-psychological testing (Computer)	Computer based test battery used to identify and monitor cognitive impairment post-SRC (18, 66, 68). Baseline testing may or may not be performed (61).	Cognitive (102).

In general the efficacy of SRC assessment tools and tests is difficult to determine due to a lack of a gold standard for comparison (102). Currently the Sports Concussion Assessment Tool is regarded as the most effective side-line SRC evaluation tool (102, 122). The most recent versions of the Sport Concussion Assessment Tool include the SCAT5 and child SCAT5 (79, 118).

The SCAT5 is a multimodal assessment tool that incorporates several SRC evaluation tests including: the Glasgow coma scale; Maddock's questions; the standardised assessment of SRC; modified balance error scoring system and a graded symptom checklist (79). The use of a combination of tests in multimodal tools such as in the SCAT5 increases both sensitivity and specificity of SRC diagnosis (102).

A recent systematic review found that multimodal assessment tools and oculomotor tests such as the King-Devick Test show relatively good sensitivity and specificity (85). The same systematic review found that balance and cognitive tests had lower sensitivity but good specificity. However these results must be interpreted with caution as studies that have evaluated SRC evaluation tests and multimodal assessment tools have provided low evidence due the high risk of bias in most of the studies (102).

Head impact sensors, in contrast to the multimodal assessment tools and oculomotor tests, were not useful tools for identifying SRC (102). Side-line video analysis however shows promise in improving the identification of SRC but further research is required to measure the sensitivity and specificity (102). Multi-time head injury assessment protocols similarly show promise in improving the identification of SRC (102, 115).

Neuro-psychological testing is a useful adjunct to monitor SRCs and provide information to make decisions about return to play (18, 66, 68). Neuro-psychological tests should preferably be assessed by a neuro-psychologist; although this is not always a requirement in computer-based testing (68). When interpreted by a neuropsychologist neuro-psychological testing is useful in assisting the doctor to make return to play and return to school decisions (66). Neuro-psychological testing is yet to be evaluated as a diagnostic tool and therefore it recommended that neuro-psychological testing be used primarily as a tool to monitor SRC and its subsequent cognitive deficits.

Neuro-psychological testing is effective in detecting post-SRC cognitive deficits. Computerised neuro-psychological testing in particular has shown to have moderate sensitivity (68). One criticism of neuro-psychological testing is that results may be easily affected by other factors not related to the SRC including disinterest in the test. Neuro-psychological tests may further be sensitive to practice effects if administered more than once in the baseline testing. Currently no consensus exists regarding the role of baseline testing and further research is required (61).

SRC causes a functional not structural disturbance the brain. Standard neuroimaging such magnetic resonance imaging and computerised tomography scanning will therefore be normal (66, 69). In recent years several more advanced imaging and laboratory tests have been developed that attempt to diagnose SRC and monitor physiological recovery from SRC. These tests include advanced neuroimaging tests such as positron emission tomography, single photon emission computerised tomography, functional magnetic resonance imaging, diffusion tensor imaging, magnetic resonance spectroscopy, and quantitative electroencephalogram (121). The use of laboratory test such as fluid biomarkers has also been proposed to monitor recovery from SRC and genetic testing is being investigated to explain the varying responses that individuals have to SRC (97, 121). Although this advanced testing shows promise in expanding our knowledge of SRC, the tests do not hold much clinical value (121). Additionally, due to the expensive and specialised equipment needed to perform these measures it is unlikely they will become part of routine SRC testing in the near future (66, 68, 69).

Summary of Identifying and Managing the Concussed Player

Appropriate identification and management of SRC is crucial to player safety (66, 102). Identification and management of SRC does not vary between males and females. If a player presents with any signs and symptoms of SRC they should be removed from the field and assessed further (66, 69). Tools such as the Concussion Recognition Tool 5 may help non-medical personnel identify SRC (114).

Once the player has been removed from the field, they should be assessed by a doctor using the SCAT5(66, 79). No gold standard exists for the diagnosis of SRC; however, the SCAT5 is considered the most useful tool (66). The doctor must further decide if hospital referral is indicated (18). If the player is diagnosed with a SRC they may not return to play on that day. All players with a diagnosed SRC should attend a follow-up with a doctor. The mainstay of SRC treatment is cognitive and physical rest in the first 24-48 hours following the injury, with a gradual increase in non-sport activity thereafter. The doctor should determine when a player may begin the graduated-return-to-sport protocol (66, 69). A minimum stand-down period of one week in adults and two weeks in players under the age of 18 is indicated before players may begin the graduated-return-to-sport protocol (99). Further research into the minimum stand-down period of female athletes is indicated, as literature suggests that females may take longer to recover from SRC than males (91).

In general research validating various SRC evaluation tools is limited and further investigation is required. Further research into SRC evaluation and management in adolescents is also required to develop more adolescent specific guidelines (66). It is clearly demonstrated that the appropriate identification and management of SRC is crucial to player safety. It is just as important that SRC be prevented (18). This will be discussed in the next section.

2.4 Prevention of Sport-related Concussion

The brain cannot be conditioned to withstand SRC, therefore prevention of SRC is key to reducing SRC incidence and its subsequent complications (18). Prevention of SRC has been recognised as one of the most effective ways to 'treat' SRC (123). General SRC prevention strategies have focused on: coaching technique, protective equipment, neck strengthening, refereeing, rules and rule enforcement, legislation, and education programmes (124). In general, current evidence concerning primary prevention strategies in SRC are limited by a lack of rigorous cohort studies and randomised control trials. Further research is thus urgently required. In rugby good tackling technique, neck strengthening, the use of protective equipment, and the implementation of injury prevention programmes have been suggested as interventions that may reduce SRC incidence (18) .

Tackling Technique

The tackle is the contact event responsible for the majority of rugby injuries including SRC (80). It follows that players should be taught correct and safe tackling technique (17, 22). Proper tackling technique is not only important to prevent injury in rugby, but is also important to improve performance (125). Few studies have specifically examined the characteristics of tackling technique that may increase risk of SRC. Most studies have evaluated what characteristics increase risk for injuries in general (126, 127). Further research into aspects of the tackle that will specifically reduce the incidence of SRC is thus required. Intervention studies evaluating tackling training will also be useful to determine what tackling training techniques are effective in reducing injury risk. As described by Finch (32) it is crucial that sports injury studies begin evaluating the efficacy and effectiveness of current injury prevention strategies, such as the teaching of safe tackling technique.

Studies that have used video-analysis at the 2011-2013 U18 South African Rugby Union boy's Craven Week Tournaments (125) and among professional men's players (127) have revealed several characteristics that are associated with sustaining an injury during the tackle. These studies showed that tackles that occur at high speed result in increased injury incidence for both the tackler and ball-carrier (126, 127). It is further thought that the difference in speed between the tackler and ball-carrier is also an important when considering injury risk, a larger difference between players may result in an increased risk of injury (58) . Reducing speed before the tackle may reduce injury incidence as it allows the tackler more time to plan the tackle (125). Reducing speed will also attenuate the force experienced in the tackle thus reducing injury risk (126). Reducing speed may be accomplished by the tackler shortening steps just before the tackle (128).

Specific aspects of the tackle place the ball-carrier at increased risk for injury. The ball-carrier is at increased risk if he is unaware of an imminent tackle and he is unable to prepare himself for impending contact (125, 129). Thus players should be coached to be aware of their surroundings at all times (125). The ball-carrier is further at high risk for SRC if tackled about the level of the shoulders.

This would be regarded as a high tackle which is illegal in rugby. A recent study found that 59% of illegal tackles at the 2011-2015 boy's South African Rugby Union U18 Youth Rugby Week Tournaments were not sanctioned by the referee. It is important that all incidences of illegal play be strictly dealt with by referees to discourage it's practice (130). It follows that a reduction in illegal high tackles will reduce the risk of SRC in rugby.

The tackler is also at higher risk for injury in specific tackling situations. For example, the tackler is at a higher risk if the ball-carrier is tackled above the sternum or below the hips. The risk also increases if the tackler makes head contact, instead of shoulder contact with the ball-carrier (125, 126). The use of shoulder tackles has also been associated with reduced injury incidence (129). A study conducted among youth players at the South African Rugby Union's 2011-2013 boy's U18 Craven Week Tournaments attempted to identify SRC injury mechanisms by video analysis. The study identified that the tackler was at increased risk for SRC if his head placement was incorrect during the tackle. On contact players that were concussed had a 'head down' position with chin tucked in (58). This study suggested that coaching should be emphasise: improving player peripheral awareness, increasing the strength of the cervical muscles, teaching safe tackling technique, and the implementation of conditioning programmes to offset the effects of fatigue. It should however be noted that these results are preliminary as the study had a sample size of only 10 injury and 83 non-injury events. Unfortunately to date no research has been conducted to evaluate contact technique and its propensity to cause injuries including SRCs in female athletes. Further research is thus indicated.

It is of critical importance that the rugby coach teaches players good tackling technique (17, 22). Younger players tend to have poorer technique (3, 21) and it is therefore suggested that tackling technique be coached from the age of 10 years (58). Several key aspects of tackling technique should be taught. The coach must teach players to be aware of their surroundings at all times so that they can anticipate a tackle and protect themselves appropriately (131). Players should also be coached to bring themselves to ground as soon as possible after being tackled (127). Lastly when tackling, players should be taught to reduce their speed just before the tackle, use shoulder contact for the tackle, place their head on the correct side, tackle the ball-carrier in his mid-section between the hips and the sternum, and use leg drive in the tackle (132).

It has also been recognised that player fatigue contributes to a deterioration of tackling technique and subsequent increased risk for injuries including SRC (3). The coach should thus ensure that tackling technique is coached in both fatigued and non-fatigued states. Appropriate conditioning of players may further help reduce the deterioration of technique as players fatigue (133). Further research into this area is needed as to date no studies have evaluated the effect of player conditioning on SRC risk.

Protective Equipment

The use of protective equipment including helmets and headgear have been proposed to assist in the prevention of SRC (124). Although helmets have been shown to be effective in reducing head injuries in cycling, snow-boarding and ski sports (134), it is unclear if helmets specifically reduce SRC risk in these sports (124). Helmets are not compulsory in rugby, although some players may choose to wear regulation headgear. Research into the effect of headgear on SRC risk in rugby remains equivocal. One study conducted among 240 male and 87 female club rugby players found that headgear was ineffective in reducing SRC risk (135). A systematic review of interventions to reduce SRC confirmed this finding (136). Studies investigating protective equipment have suffered from various methodological flaws such as self-report bias and the use of convenience samples. Further well-designed trials are thus required (123).

A cluster randomised control trial conducted to assess the efficacy of padded headgear in male rugby players aged 13-18 years found the headgear had no effect on SRC (137). In contrast, Hollis et al (86) and Kemp et al (65) found that headgear reduced the risk of SRC in non-professional and elite male rugby players respectively. It has also been suggested that the use of headgear may place a player at increased risk as they feel more comfortable engaging in riskier behaviour on the field. This in turn may place them at increased risk of sustaining a SRC or other injury (138). A recent study conducted among collegiate male rugby players in the United States of America found that 40% of players believed that headgear protected them from SRC (139). These players were four times more likely to play with increased aggression than those that did not believe the headgear was protective.

In a study conducted in South Africa 78% of a group of male sub-elite players believed that a scrum cap would offer effective protection from SRC (140). Although further research is indicated to determine if headgear use changes the risk of SRC, it may be warranted that players at least be educated that headgear has currently been shown to be ineffective in reducing SRC (139) . World Rugby currently suggests that headgear should not be used by players as headgear is not only ineffective in preventing SRC, but also may results in players engaging in more risky behaviour (141).

The use of mouth guards has also been suggested to reduce SRC risk. Mouth guards are proposed to reduce biomechanical force transmission to the brain after a blow to the head (124). Whether or not this reduced force transmission results in reduced SRC incidence is unclear. A recent systematic review conducted by Emery et al (134) found an insignificant protective effect of mouth guards in contact sports.

Injury Prevention Programmes

In recent years rugby injury prevention programmes, focussing on coach and referee education have been developed. The first rugby injury prevention programme (RugbySmart) was launched in New Zealand in 2001. The RugbySmart programme was effective in reducing injury rates, including SRC incidence (142). The Heads-Up programme in the United States of America was effective in improving coach SRC knowledge. However it is unclear if this has resulted in a reduced SRC incidence (143).

Based on the success of the RugbySmart programme, the South African BokSmart programme was introduced by the South African Rugby Union in 2009 (29, 30). BokSmart aims to reduce injury rates by influencing player behaviour through coach and referee education. BokSmart includes four main elements: a compulsory DVD facilitated rugby safety workshop, an entry level first aid course aimed at underprivileged rugby playing communities, a toll free BokSmart Spineline that assists with management and transfer to the nearest medical facility of all head, neck and spinal cord injurie, and freely accessible online educational resources (30). Additionally, coaches are all provided with the Concussion Recognition Tool 5. Attendance by coaches at rugby safety workshops has been mandatory since 2010.

Coaches must attend the workshop and renew their accreditation every second year (30). BokSmart has been effective in reducing serious injury rates in junior players (144). The programme has also resulted in a change in attitude of the players which has resulted in safer tackling and scrumming techniques (145). BokSmart has identified SRC as a key issue to be addressed in the programme (30).

Most research on SRC in rugby has focused on male adult players (20) and as a consequence the findings from these studies have guided injury prevention programmes. According to Finch (32) and van Mechelen (31) a firm understanding of injury incidence and aetiology is required before effective injury prevention programmes can be developed. Since data on youth and female players is lacking, the injury prevention programmes cannot be customised for these groups. The suggests that further research on youth and female players is needed.

Summary of Sport-related Concussion Prevention

The teaching of good tackling technique is fundamental to preventing injury and SRC in rugby. Currently there is insufficient evidence to support the use of protective equipment in rugby including headgear (134, 136) and mouth guards. Further research into aspects of technique that may specifically reduce SRC risk is required (17, 22). Further research identifying if programmes aiming to improve tackling technique are effective in both improving technique and reducing SRC are also required.

Prevention of SRC in youth rugby is particularly important as youth are more vulnerable to SRC, and take longer to recover than adults. Prevention of SRC in female rugby players is also crucial because as discussed previously, there is evidence that females take longer to recover from SRC and have more adverse symptoms than males. According to the Van Mechelen's injury prevention model injury incidence and mechanism must be determined before effective injury prevention strategies can be implemented (31) .

Unfortunately, most SRC research, particularly in rugby has focused on male athletes. Further research into SRC prevention strategies in youth male and female rugby is therefore required. This will contribute to more customised injury prevention programmes for these specific population groups.

2.5 Summary of the Literature

Rugby is a popular sport worldwide and within South Africa (1). Rugby enjoys particular popularity among the youth. The number of youth players has increased significantly in recent years with a particular increase in the number of girls participating in the game (16).

Due to the physical nature of the game the incidence of injury is relatively high (17). SRC is one of the most common injuries reported in rugby (18-20). SRC is defined as a complex pathophysiological process that causes a functional disturbance to the brain (69, 146, 147). A number of SRC complications are possible. Complications may have devastating outcomes. Persistent post-concussive symptoms may further significantly affect quality of life (9, 30). SRC occurs most frequently during matches and often in the tackle (80).

SRC incidence in youth rugby is high. In male youth rugby, an incidence rate of between 0.2-1.8 SRC per 1000 match playing hours has been reported (7, 20, 21). A study conducted in South Africa demonstrated a higher incidence of 5.8 SRC per 1000 match playing hours in male youth players in the 2011-2013 Craven Week Tournaments (22). The high incidence of SRC in youth rugby is concerning as it is currently thought that youth players may be more vulnerable to developing SRC (7). Youth athletes are at particular risk for suffering persistent post-concussive symptoms. They are further reported to take longer to recover from a SRC than an adults (28).

To date few studies have investigated the SRC incidence among youth female rugby players. Research among adult female rugby players is also limited. Incidences of between 0.3 and 1.6 SRC per 1000 playing hours have been previously reported in this population (28, 29). The lack of research into SRC among female rugby players is concerning as it is suggested that female athletes may be even more vulnerable to developing SRC than their male counterparts (11). Female athletes may also take longer to recover from SRC than males (13-15).

In recent years, several rugby injury prevention programmes have been developed. The South African BokSmart programme was introduced by the South African Rugby Union in 2009 (29, 30). To date injury prevention programmes have been developed using research that has focused on mostly adult male players. It therefore cannot be assumed that this research applies to youth players or female players (20). According to Finch (32) and van Mechelen (31) injury incidence, aetiology and mechanism must be described before effective injury prevention programmes can be implemented. Further research in these groups are thus required. World Rugby have changed laws of the game to make the game safer when there is compelling evidence of risk. Thus, further research into youth rugby, particularly female youth rugby may contribute to the pool of evidence that may eventually help inform changes to these versions of game, to improve player safety.

The study in Chapter Three will therefore aim to determine the incidence of SRC and SRC mechanism of injury in Under-13 (U13) to Under-18 (U18) youth male rugby players and Under-16 (U16) to U18 youth female rugby players at the 2011-2018 and 2015-2018 South African Rugby Union Youth Week Tournaments respectively. The study will also determine potential factors associated with the development of SRC in these players. The study will further compare mechanism of injury between male and female players and between various age groups. Lastly, it will describe potential contributing factors to developing a SRC in male and female youth players.

Chapter Three: Sport-related Concussion Incidence and Mechanism of Injury in Male and Female Players at the South African Youth Week Rugby Tournaments: 2011-2018

3.1 Introduction

Rugby is a popular sport worldwide and within South Africa (1). In recent years there has been a significant increase in the number of girls participating in the sport (16). SRC in youth rugby is high. This is concerning as youth players are thought to be more susceptible to developing SRC and its complications. Youth players are also thought to take longer to recover from SRC than adult players (7, 10). Previous systematic reviews have reported injury incidences of 0.2 to 10.6 SRC per 1000 match playing hours among male youth players (20); and 0.2-6.9 SRC per 1000 match playing hours among male and female youth players (7). In South Africa studies conducted among male youth players have reported SRC incidences of 6.8 (82) and 5. 8 (58) SRC per 1000 match playing hours. SRC occurs most commonly during the contact phases of the game. The tackle has been repeatedly recognised as the contact event resulting in the highest proportion of concussions (58, 80, 83).

Females are thought to be more susceptible to SRC than their male counterparts (12, 91). Female players are also thought to take longer to recover from SRC and have a higher chance of experiencing persistent post-concussive symptoms (15). Unfortunately to date there is scarce literature that describes SRC incidence and mechanism of injury in youth female rugby players (20). In South Africa no studies have been conducted investigating SRC incidence in female youth rugby players. Some research has been conducted at the elite level of female rugby participation. The SRC at the 2006 Women's Rugby World Cup was 0.3 SRC per 1000 match playing hours (23). An incidence of 1.6 SRC per 1000 match playing hours has also been reported among collegiate female players (24).

In recent years a number of rugby injury prevention programmes have been developed. The BokSmart programme was launched in South Africa in 2009 (29, 30) and developed data driven intervention programmes. Due to the lack of research into SRC among youth players, particularly female players, injury prevention programmes are forced to rely on data drawn mostly from studies of adult male players. According to Van Mechelen's injury prevention principles it crucial to know the incidence and mechanism of an injury before an effective injury prevention strategy can be planned (31). Finch's TRIPP model similarly states the injury incidence and mechanism of injury must be known before effective injury prevention can be implemented (32) Further research is thus required among youth male and female players to ensure that injury prevention programmes are appropriate for these two vulnerable groups. Accordingly, the purpose of this study was to determine, and compare the SRC incidence and mechanism of injury among male and female youth players at the 2011-2018 and 2015-2018 South African Rugby Union Youth Week Tournaments respectively.

3.2 Methods

Study Design

The study had a retrospective, epidemiological design. The study reviewed SRC injury data collected at the 2011-2018 South African Rugby Union Youth Week Rugby Tournaments. The study was submitted to and approved by the Faculty of Health Sciences Human Ethics Research Committee, University of Cape Town *(Appendix I).*

Participants

Injury surveillance information of rugby players who sustained a SRC at the 2011-2018 South African Rugby Union Youth Week Rugby Tournaments was included in this study's retrospective analysis. The South African Rugby Union Youth Week Tournaments for this particular study included male players participating in U13-U18 age groups and female players participating in U16 and U18 age groups. Data for female players was only collected from 2015, as prior to 2015 no female South African Youth Rugby Week Tournaments existed.

Inclusion Criteria

Injury surveillance information of all rugby players who sustained a SRC at the 2011-2018 South African Rugby Union Youth Week Rugby Tournaments. All players and parents/guardians provided signed informed consent before the tournament and gave permission for their injury data to be analysed.

Exclusion Criteria

There were no exclusion criteria.

Sample Size

Total population sampling was used. Thus, all concussive injuries reported at the 2011-2018 South African Rugby Union Youth Week Tournaments were included in the study. This represented a total of 266 recorded SRCs. Each data set belonged to one player, thus the SRC data of 266 players was included in the study.

Measurement Instruments

Relevant data from the injury surveillance database was extracted for the purposes of this study. Only data describing SRC injuries were included. Further, only data relevant to this study's aims and objectives were included for analysis. These data included player demographics, tournament information, player exposure time, mechanism of injury, SRC injury information, and protective equipment utilised. The data extraction sheet utilised at each tournament is shown in *Appendix II*. Data on SRC were collected according to the injury definitions and guidelines proposed by World Rugby's 2007 consensus statement on injury definitions and data collection procedures for studies of injuries in rugby (44).

The consensus statement defines an injury 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, 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" (44).

Player demographic data included: player date of birth, age, height (cm), weight (kg), ethnicity, player rugby union, player position, positional group (forward or backline player), number of years playing in that position, and if the player had medical insurance or not.

Tournament data included: year of tournament and which youth week tournament the player was participating in. Tournaments included the boy's U13 Craven Week Tournament, boy's and girl's U16 Grant Khomo Week, girl's U16 Academy Week, boy's and girl's U18 Academy Week Tournaments, and boy's U18 Craven Week Tournament. Player game exposure time in hours for each tournament was also included to calculate injury incidence. Injury incidence and 95% confidence intervals was calculated according to the method described by Knowles et al (148):

Injury incidence = (number of injuries)/number of matches x number of players (15) x match duration (hours) x 1000.

Data potentially contributing to SRC were included in the analysis. These data consisted of:

- The match quarter in which the SRC occurred.
- Whether the player was a starter (played from the beginning of the game) or substitution (replaced another player and did not play from the start of the game).
- The type of injury event (tackle, scrum, ruck, open-play, line-out, running, kicking).
- The primary mechanism of injury.

- Whether foul play was associated with the injury, and if so, whether the match referee cited the foul play.

Data related to the SRC itself was also extracted. These data included:

- Date of injury.
- Whether the player continued the game or was removed from play.
- End date of injury (players were contacted by researchers after the tournament to determine when they returned to play)
- Number of days the player was unable to participate in rugby.

All injuries were initially described as medical attention injuries. Medical attention injuries were then filtered into medical attention injuries (without time-loss) and time-loss injuries. A medical attention injury (without time-loss) is defined as an injury that requires medical attention but the player is still able to continue with the game or he is able to train in the 24 hours post injury (44). A time-loss injury is an injury that requires medical attention and the player is unable to participate fully in rugby training or match play for one day or more (44). Lastly data extracted associated with protective equipment described whether the concussed player was using a mouth guard or headgear at the time of injury.

Validity and Reliability

Data collected by the injury surveillance team was carried out according to the World Rugby's consensus statement (44). A researcher was present in the medical tent and recorded the information while the medical doctor on duty was attending to the injured player. Although the same researcher did not collect data at each tournament, all researchers underwent training before each tournament to familiarise themselves with the data collection procedures. Central co-ordination of these researchers remained constant throughout the period of data collection.

3.3. Statistical Analyses

Statistical analysis was performed using *IBM SPSS Statistics, Version 25*. Descriptive statistics were used to described player demographics, tournament-related data, and data pertaining to the mechanism of the SRC and the SRC itself. A frequency analysis of the data set was first performed. SRC incidence was expressed as SRC injuries per 1000 playing hours (and 95% confidence intervals) using the method suggested by Knowles et al The significance test for the difference in two injury rates described by Gissane (149) was used to determine if a difference in SRC incidence existed between males and females; and to determine if a difference in incidence existed between male U13, U16 and U18 age groups; and U16 and U18 female age groups (148). Injury risk ratios (IRR) were calculated to quantify the difference in SRC incidence between males and females; and between male U13, U16 and U18 age groups; and U16 and U18 female age groups. Chi-square tests were further used to determine if differences in mechanism of injury existed between male and female youth players; and to determine if differences in SRC mechanism of injury existed between age groups. Lastly, chi-square tests were used to determine factors associated with SRC. Statistical significance was accepted as $p < 0.05$.

3.5 Results

Player Characteristics

Height, weight and Body Mass Index (BMI) increased from U13 to U18 age groups in boys. Girls showed similar height, weight and BMI in U16 and U18 groups.

Table 3.5.1: Concussed player characteristics at each tournament (n=number of players)

	Boys U13	**Girls U16**	**Boys U16**	**Girls U18**	**Boys U18**
Age (years)	13, 12-13 (n=63)	15, 14-16 (n=14)	16, 15-16 (n=48)	17, 16-18 (n=25)	17, 16-18 (n=98)
Height (cm)	167.3 ± 9.3 (n=56)	166.5 ± 6.5 (n=4)	178.2 ± 8.3 (n=45)	168.0 ± 10.1 (n=6)	180.4 ± 8.5 (n=79)
Weight (kg)	60.4 ± 11.6 (n=56)	71.8 ± 18.3 (n=5)	82.3 ± 15.0 (n=46)	67.9 ± 15.4 (n=7)	85.7 ± 12.6 (n=80)
BMI (kg/m²)	21.5 ± 3.0 (n=56)	27.1 ± 4.8 (n=4)	25.8 ± 3.9 (n=45)	24 ± 4.0 (n=6)	26.2 ± 3.3 (n=79)

*Age values are presented as median and ranges.
*Height, weight and BMI are presented as mean ± SD.

Sport-related Concussion Incidence

A total of 266 SRCs were recorded at the 2011-2018 South African Rugby Union Youth Week Tournaments. A total of 774 team squads participated in the tournaments, each squad included 22 players. Overall player hours for all tournaments was 37985 hours. The overall SRC incidence across all tournaments from 2011-2018 was 7.0 SRC per 1000 match playing hours (95% CI, 6.2-7.8) (Table 3.5.2).

Sex

SRC incidence for all male players from 2011-2018 was 6.9 SRC per 1000 match playing hours (95% CI, 6.0-7.8) SRC incidence for all female players from 2016-2018 was 7.6 SRC per 1000 match playing hours (95% CI, 5.3-9.9).

No significant difference was existed between overall SRC incidence in male and female players. Further no statistical difference in SRC incidence was found between male and female players of the same age group. No significant difference was found between SRC incidence in boys U16 and girls U16 groups (p=0.87); and between boys U18 and girls U18 groups(p=0.17).

Age Group

SRC incidence from 2011-2018 was 10.7 (95% CI, 8.2-13.1), 7.5 (95% CI, 5.5-9.6) and 5.3 (95% CI, 3.4-6.5) SRC per 1000 match playing hours for boys U13, U16 and U18 age groups respectively (. SRC incidence from 2015-2018 was 7.2 (95% CI, 3.7-10.2) and 7.9 (95% CI, 4.7-10.9) SRC per 1000 match playing hours for girls U16 and U18 age groups respectively. SRC incidence for each age group per tournament is represented in Table 3.5.2.

SRC incidence was significantly higher in the boys U13 age group when comparing boys U13 and U18 age groups (IRR 2.0; 95% CI, 1.5-2.7; p=0.00014). U13 boy players were twice as likely to sustain a SRC than their U18 counterparts. There were no other significant differences between age groups of the same sex. There were no significant differences in incidence of SRC between the boys U13 and U16 groups (IRR 1.41; p=0.06); boys U16 and U18 groups (IRR 1.42; p=0.11); and girls U16 and U18 groups (IRR 1.1; p=0.77).

Table 3.5.2: SRC incidence per 1000 match playing hours (±95% CI) per tournament from 2011 to 2018

	Boys U13	Girls U16	Boys U16	Girls U18	Boys U18
2011	4.2 (-0.5 - 8.9)	-	7.4 (1.5-13.3)	-	4.2 (-0.5-8.9)
2012	6.9 (0.9 – 13.0)	-	6.7 (1.3-12.0)	-	6.9 (0.9-13.0)
2013	2.8 (-1.1 - 6.6)	-	12.2 (5.0-19.4)	-	2.8 (-1.1-6.6)
2014	15.6 (7.4 - 23.7)	-	10.0 (3.5-16.5)	-	5.0 (2.2 -7.8)
2015	8.9 (2.7 – 15.0)	4.2 (-0.5-8.9)	3.3 (-0.4-7.1)	9.5 (2.9-16.1)	2.6 (0.5-4.7)
2016	20.0 (10.8 - 29.2)	6.4 (0.8-12.0)	11.1 (4.2-18.0)	10.7 (3.7-17.7)	8.2 (4.5-11.9)
2017	10.0 (3.5 - 16.0)	-	5.6 (0.7-10.4)	2.6 (-1.0-6.2)	8.7 (4.9-12.5)
2018	13.3 (5.8 - 20.9)	11.1 (3.4-18.8)	3.7 (-0.5-7.9)	8.3 (2.2-14.5)	1.2 (-0.2-2.6)
Combined 2011 – 2018	**10.7 (8.2 - 13.1)**	**7.2 (3.7-10.2)**	**7.5 (5.5-9.6)**	**7.9 (4.7-10.9)**	**5.3 (4.3-6.4)**

Sport-related Concussion Injury Event

Overall the injury event that resulted in the most SRCs was the tackle (65%). The second most common injury event resulting in SRC was the ruck (20%) (Table 3.5.3). Table 3.5.3 only represents SRC recorded that noted the injury event. Thirteen percent of recorded SRCs did not note the injury event.

Table 3.5.3: Injury event resulting in SRC

	Boys U13		Girls U16		Boys U16		Girls U18		Boys U18	
Injury Event	**Frequency**	**%**	**Frequency**	**%**	**Frequency**	**%**	**Frequency**	**%**	**Frequency**	**%**
Tackle	37	60	10	72	29	59	13	72	62	70
Ruck	10	16	2	14	14	29	3	17	17	19
Kicking	1	1	-	-	-	-	-	-	1	1
Lineout	3	5	1	7	1	2	-	-	-	-
Maul	1	2	-	-	1	2	-	-	-	-
Open Play	5	8	-	-	3	6	1	5.5	9	10
Running	3	5	-	-	-	-	-	-	-	-
Scrum	2	3	1	7	1	2	1	5.5	-	-
Total	**62**	**100%**	**14**	**100%**	**49**	**100%**	**18**	**100%**	**89**	**100%**

SRC incidence resulting from the tackle was 5.6 (95% CI, 3.8-7.3), 4.1 (95% CI, 2.6-5.6) and 3.3 (95% CI, 2.5-4.1) SRC per 1000 match playing hours in boys U13, U16 and U18 players respectively. In girls SRC incidence resulting from the tackle was 4.5 (95% CI, 1.2-4.9) SRC per 1000 match playing hours for both U16 and U18 players. Boys U13 players were significantly more likely to sustain a SRC from a tackle than boys U18 players ($p= 0.01$). There were no other significant differences found between age groups ($p=0.23$ when comparing boys U13 and U16 players; $p=0.31$ when comparing boys U16 and U18 players; $p=0.38$ when comparing girls U16 and U18 players). Further there were no significant differences when comparing sexes ($p=0.81$ when comparing boys and girls U16 players; and boys and girls U18 players).

Only 42% of tackle events recorded noted if the SRC was sustained by the tackler or ball-carrier. Of this 42%, 63% of SRCs that occurred during the tackle were sustained by the ball-carrier. The remaining 37% of SRC's were sustained by the tackler. The distribution of injuries occurring to the tackler versus ball-carrier are represented in Table 3.5.4. The ball-carrier sustained a higher percentage of tackles in all groups except the boys U16 group and the girls U18 group. In the boys U16 group injuries to the tackler and ball-carrier were equal (50% each). In girls U18 players 44% of injuries occurred to the ball-carrier and 56% to the tackler.

Table 3.5.4: Tackle-related SRC occurring in the tackler vs ball-carrier (n=number SRC per group)

	Boys U13 (n=71)			Girls U16 (n=16)			Boys U16 (n=53)			Girls U18 (n=26)			Boys U18 (n=100)		
	Frequency	**%**	**Valid %**	**Frequency**	**%**	**Valid %**	**Frequency**	**%**	**Valid %**	**Frequency**	**%**	**Valid %**	**Frequency**	**%**	**Valid %**
Ball-carrier	18	49	90	5	50	62	3	10	50	4	31	44	10	16	48
Tackler	2	5	10	3	30	38	3	10	50	5	38	56	11	18	52
Not recorded	17	46	-	2	20	-	23	80	-	4	31	-	41	66	-
Total	**37**	**100%**	**100**	**10**	**100%**	**100%**	**29**	**100%**	**100%**	**13**	**100%**	**100%**	**62**	**100%**	**100%**

*Note: % refers to percentage of tackles calculated including tackles where it was not recorded if the tackler or ball-carrier sustained the tackle.
*Note: Valid % refers to percentage of tackles calculated excluding tackles where it was not recorded if the tackler or ball-carrier sustained the tackle.

SRC incidence resulting from the ruck was 1.5 (95% CI, 0.6-2.4), 2.0 (95% CI, 0.9-3.0), 0.9 (95% CI, 0.5-1.3) SRC per 1000 match playing hours for boys U13, U16 and U18 players respectively. In girls, the ruck resulted in SRC incidence per 1000 playing hours of 0.9 (95% CI, -0.3-2.0) and 0.6 (95% CI, -0.2-1.5) for U16 and U18 age groups respectively. Boys U16 players had a significantly greater incidence of SRC resulting from the ruck than boys U18 players (p=0.02). There were no other significant differences between age groups (p=0.49 when comparing boys U13 and U16 age groups; p=0.20 when comparing boys U13 and U18 age groups) or sexes (p=0.28 when comparing boys and girls U16 players; p=0.99 when comparing boys and girls U18 players).

Sport-related Concussion Mechanism of Injury

Overall the most common primary mechanisms of injury were front-on tackles (27%) and collisions (18%). The front-on tackle and collision were the most common of all mechanisms of injury across all groups, with the exception of the girls U18 and boys U13 age groups. In girls U18 the front-on tackle (31%), tackle from behind (15%) and cleaning (15%) were the most common mechanisms of injury. In boys U13 injuries occurring in landing (15%) were equal to those occurring during the front-on tackle (15%) (Table 3.5.5). Twenty-nine percent of SRCs in the dataset did not record the primary mechanism of SRC. Table 3.5.5 only represents the SRCs that recorded the primary mechanism of SRC.

Table 3.5.5: Primary mechanism of SRC

	Boys U13		Girls U16		Boys U16		Girls U18		Boys U18	
Injury mechanism	**Frequency**	**Percent (%)**	**Frequency**	**Percent (%)**	**Frequency**	**Percent (%)**	**Frequency**	**Percent (%)**	**Frequency**	**Percent (%)**
Tackle front-on	8	15	2	29	16	36	4	30	22	30
Collision	15	29	2	29	10	23	1	8	7	9
Tackle from behind	1	2	-	-	2	5	2	15	1	1
Tackle side-on	3	6	-	-	3	7	1	8	14	19
Cleaning	3	6	-	-	1	2	2	15	7	9
Kneed	1	2	1	14	3	7	-	-	11	15
Kicked	7	13	1	14	1	2	-	-	2	3
Landing	8	15	-	-	5	11	-	-	4	5
Head Butt	1	2	-	-	-	-	1	8	1	1
Popped scrum	-	-	1	14	-	-	1	8	-	-
Rucked	-	-	-	-	1	2	1	8	-	-
Double tackle			-	-	-	-	-	-	3	4
Elbowed	2	4	-	-	-	-	-	-	-	-
Jumping			-	-	-	-	-	-	3	4
Punched	-	-	-	-	2	5	-	-	-	-
Not supported	1	2	-	-	-	-	-	-	-	-
Scrum engagement	1	2	-	-	-	-	-	-	-	-
Slipped	1	2	-	-	-	-	-	-	-	-
Total	52	100%	7	100%	44	100%	13	100%	75	100%

SRC incidence resulting from collisions was 2.3 (95% CI, 1.1-3.4), 1.4 (95% CI, 0.5-2.3) and 0.4 (95% CI, 0.1-0.6) SRC per 1000 match playing hours in boys U13, U16 and U18 players respectively. SRC incidence resulting from collisions in girls was 0.9 (95% CI, -0.3-2.1) and 0.3 (95% CI, -0.3-0.9) SRC per 1000 match playing hours in girls U16 and U18 players respectively. U16 boy players had a significantly higher rate of SRCs caused by collisions than U18 boy players (p=0.00007). Similarly, U13 boy players had a significantly higher incidence of SRC caused by collisions than U18 boy players (p=0.003). No other significant differences occurred between age groups (p=0.23 when comparing boys U13 and U16 players; p=0.35 when comparing girls U16 and U18 players). Further no difference was found when comparing sexes (p=0.55 when comparing boys and girls U16 players; p=0.85 when comparing boys and girls U18 players).

SRC incidence resulting from front-on tackles was 1.2 (95% CI, 0.7-1.7) SRC per 1000 match playing hours in boys U13, U16 and U18 age groups. SRC incidence resulting from front-on tackles in girls U16 and U18 players was 0.9 (95% CI, 0.3-2.1) and 1.2 (95% CI, 0.0-2.4) SRC per 1000 match playing hours respectively. U16 boys had a significantly higher rate of SRC's due to front-on tackles when compared to U18 boys (p=0.04). No other significant differences existed between age groups (p=0.13 when comparing boys U13 and U16 players; p=0.95 when comparing boys U13 and U18 players; p=0.73 when comparing girls U16 and U18 players). Further no difference occurred between sexes (p=0.20 when comparing boys and girls U16 players; p=0.95 when comparing boys and girls U18 players).

SRC occurring due to foul play occurred in 7% of SRCs. The high tackle was the foul play event that most commonly resulted in a SRC (82%). SRC occurring due to foul play events was lowest in the girls U18 group (0%) and highest in the boy U13 and U16 groups (10%) (Table 3.5.6). The referee took action in 39% of foul play events. Table 3.5.6 only represents SRC where it was recorded if a foul play event took place. Twenty percent of SRCs recorded did not note if the SRC occurred due to foul play.

Table 3.5.6: SRC resulting from foul play events

	Boys U13		Girls U16		Boys U16		Girls U18		Boys U18	
Foul Play?	**Frequency**	**%**	**Frequency**	**%**	**Frequency**	**%**	**Frequency**	**%**	**Frequency**	**%**
Yes	54	90	15	94	36	90	20	100	74	95
No	6	10	1	6	4	10	0	0	4	5
Total	60	100%	16	100%	40	100%	20	100%	78	100%

SRC incidence per 1000 match playing hours during a foul play event was 0.9 (95% CI, 0.2-1.6), 0.6 (95% CI, 0.0-1.1) and 0.2 (95% CI, 0.0-0.4) for boys U13, U16 and U18 groups. SRC incidence per 1000 match playing hours during a foul play event was 0.5 (95% CI, -0.4-1.3) for the girls U16 group per 1000 match playing hours. No SRC occurred due to a foul play event in the girls U18 group. No significant differences occurred between age groups (p=1.00 when comparing boys U13 and U16 players; p= 0.20 when comparing boys U13 and U18 players; p=0.60 when comparing boys U16 and U18 players; p=0.22 when comparing girls U16 and U18 players) or between sexes (p=0.36 when comparing boy and girls U16 players; p=0.10 when comparing boys and girls U18 players).

Factors associated with Sport-related Concussion

Tournament day

The majority of SRC occurred on day one (26%) and two (27%) of the tournaments. The least SRC occurred on day six where only 1% of SRC occurred. SRC were significantly more likely to occur on day two than day four (p=0.0008), day five (p=0.0002) and day six (p<0.001). No significant differences in SRC were found between day one and day two and day two and day three.

Match quarter

Overall the SRC incidence for each match quarter was 1.2 (95% CI, 0.8-1.5), 1.5 (95% CI, 1.1-1.9), 1,6 (95% CI, 1.2-2) and 2.1 (95% CI, 1.6-2.5) SRC per 1000 match playing hours for the first, second, third and fourth match quarters respectively. No significant differences existed in SRC incidence between match quarters.

Playing position

Overall the SRC incidence for forwards was 3.7 (95% CI, 3.0-4.1) SRC per 1000 match playing hours. The SRC incidence for backs was 3.1 (95% CI, 2.6-3.7) SRC per 1000 match playing hours. No significant difference in SRC incidence existed between forwards and backs.

Protective equipment

Overall, there was a significant difference in SRC incidence between players who wore headgear and those who did not. Players who did not wear headgear were more likely to sustain a SRC than those who did ($p<0.001$). No significant differences SRC incidence occurred between players who wore or did not wear mouth guards.

Management of Sport-related Concussion

Of the 266 SRCs identified from 2011-2016, 86% of players were removed from play immediately after sustaining a SRC. Fourteen percent of concussed players continued to play the game. Fifty-two percent of players that sustained a SRC returned to play before 19 days (the minimum time it should take a youth player to return to play). On average players missed 7.14 days.

Chapter Four: Discussion and Conclusion

4.1 Discussion

Sport-related Concussion Incidence

The overall incidence of SRC at the 2011-2018 South African Rugby Union Youth Week Tournaments was 7.0 SRC per 1000 match playing hours. This incidence is only slightly higher than the upper range of SRC reported by a 2015 systematic review that reported an incidence of between 0.2-6.9 SRC per 1000 match playing hours in youth rugby players (7). It could be theorised that the slightly higher incidence of SRC in this study is due to an increased focus and awareness on the identification and correct management of SRC in recent years. Strict SRC policies applied at the South African Rugby Union Tournaments; and availability of medical staff to assess potential SRCs could also have resulted in the higher SRC incidence reported by this study (82). Further the observational nature of the study may also have resulted in improved identification of SRC. Also this study was not reliant on self-reported SRCs, which usually results in underreporting particularly by youth players (70) .

Overall SRC incidence for male players from U13 to U18 age groups was 6.9 SRC per 1000 match playing hours. This value falls comfortably in ranges in reported by a 2014 systematic review of SRC. The systematic review conducted by Gardner et al (20) found a SRC incidence of between 0.9 and 10.6 per 1000 match playing hours in school boy players. This study's incidence is also similar to previous studies conducted in South Africa that reported a SRC incidence of 5.8 SRC per 1000 match playing hours at the 2011-2013 Craven Week Tournaments (22) and 6.8 SRC per 1000 match playing hours at the 2011-2014 boy's South African Rugby Union Youth Week Tournaments (82) .

This study is unique as it describes SRC in youth female rugby players. To date no studies have specifically reported SRC incidence in youth female rugby (20). Further no evidence exists describing SRC in South African female players of any age group. Overall SRC incidence for female players from U16 to U18 age groups was 7.6 SRC per 1000 match playing hours. This study shows a much higher incidence of SRC than previous studies that have reported SRC incidence in adult female players. An incidence of 0.3 SRC per 1000 match playing hours was reported at the 2006 Women's Rugby World Cup (23) . Further a SRC incidence of 1.6 SRC per 1000 match playing hours was reported among American collegiate female players (24). It is currently thought that in male rugby SRC and overall injury incidence increases as the players gets older and competition levels increase (20). Increases in injury risk as the player ages occurs due to increases in player physical stature, competitiveness and aggression of players, increased game speed, increased foul play, and longer length of the rugby season (36, 37). However, the results of this study suggest that this trend might not occur with female players. Unfortunately, due to the dearth of research into SRC in adult and youth female players, further research is required to provide more substance to this observation. This study further contradicts the premise that SRC increases as male players get older. For example, the study showed that SRC was significantly higher in U13 players (10.7 SRC per 1000 match playing hours) when compared to U18 players (5.3 SRC per 1000 match playing hours. An U13 male player was twice as likely to sustain a SRC than an U18 male player. Although little research has been conducted, particularly in rugby, it is thought that a higher injury incidence in younger players may be explained by biological and physiological changes taking place during growth and maturation (150). Growth and maturation will be discussed further below. As this study was only able to investigate SRC incidence in U16 and U18 girl players it remains to be discovered if a similar trend of higher SRC in U13 players would be found amongst youth females. Further research is thus required in this area. The high incidence of SRC identified in female players by this study is concerning as the severity of SRC and risk for potential complications is thought to be higher in youth athletes (7), particularly female athletes (11, 13-15). The number of girls participating in rugby has also increased significantly (6, 16) in recent years, thus increased research focus needs to be placed on this group.

Current evidence suggests that SRC incidence may be higher in females than males (11). There are various biomechanical and hormonal theories to explain why females may be more susceptible to SRC (14, 15, 91). Female athletes are also more likely to report SRC than their male counterparts (90, 93). However, this study showed no significant difference in SRC incidence between male and female players. These findings may suggest that SRC between youth male and female rugby players is similar. Unfortunately, due the fact that data on girls SRC were only available from 2015, these findings are preliminary and further research is required to confirm this finding. According to van Mechelen's (31) injury prevention principles and Finch's (32) more recent TRIPP guidelines it is crucial that injury incidence be accurately identified (31). As injury incidence in this study was similar amongst boys and girls it can be theorised that injury prevention programmes implemented amongst these groups could also be similar.

SRC incidence was highest in the boys U13 age group. There was a significant difference between SRC in boys U13 and U18 age groups. U13 players were twice as likely to sustain a SRC than U18 players. This observation is interesting as most previous research has reported an increase in SRC as players get older (20). Within youth rugby itself injury incidence is thought to increase as players progress through age groups due to the increased physicality of the game, increased player physical stature, increased player aggressiveness, and longer time spent on the field (8, 21). The results of this study align with results reported by previous studies conducted among youth players in South Africa. Mc Fie et al (82) found that U13 players were more likely to sustain SRC than U18 players at the 2011-2014 South African Rugby Union Youth Week Tournaments (82). It must be noted that the study conducted by Mc Fie et al (82) used a portion of the database (2011-2014) used by this study (2011-2018). Its results confirm a continued trend over the preceding years of higher SRC incidence in U13 players. It has been theorised that higher incidence rates in younger rugby players may occur due to poorer physical, motor and cognitive development; as well as poor contact technique (82). Further research however is required to confirm these findings. A number of studies investigating injury risk in male youth football players have found that injury risk is associated with the growth and maturation of players. Risk of injury seems to be particularly high at a growth stage know as peak height velocity.

One study conducted amongst 76 young male football players found that injury incidence in players circa-peak height velocity was as high as 24.5 injuries per 1000 player hours (150). Peak height velocity refers to the growth period where maximal growth occurs (151). In boys peak height velocity has been reported to occur at 13.5 ± 1.8 years of age and 11.5 ± 1.8 years of age in girls. The period of peak height velocity is thought to be associated with a period of 'adolescent awkwardness' where disruptions in neuromuscular control occur, potentially increasing risk of injury (152). During the period adolescents may experience delays or regressions of sensori-motor functions (150); as well as alterations in postural and balance control (152). Although not investigated in this study it is likely that many of the U13 boys included in this study may have been in the peak height velocity period which could explain the increased incidence of SRC in this group. Further investigation is however indicated. Another explanation for the U13 boys having a higher SRC incidence is that younger adolescents are thought to have poorer perceptual and motor skills (153). A recent study investigating reaction time, peripheral awareness and eye-hand-foot co-ordination found that these skills all improved with age amongst a group of male football players (aged 10-16 years) (153). It is logical to reason that players with poorer perceptual and motor skills may well have an increased injury risk. It is further interesting to note that U13 boys in this study frequently sustained SRC due to collisions. It could thus be theorised that a lack of peripheral awareness in this group may be responsible for an increased incidence of SRC. Further research should that investigate why SRC is highest in this age group.

Sport-related Concussion Injury Event

According to van Mechelen's injury prevention principles (31) and Finch's TRIPP model (32) identifying injury aetiology and mechanism is crucial to develop an effective injury prevention strategy (31). This study found that SRC occurred most commonly during the tackle (65%). The tackle was responsible for 64% of SRC in boys and of 72% of SRC in girls. This aligns with previous studies conducted among youth male players, which have reported that 44% (81) and 62% (82) of SRC occurred during the tackle. Accordingly teaching safe tackling technique can be considered a crucial aspect of SRC prevention programmes in both boys and girls. Further research needs to identify specific aspects of the tackle that might increase risk of SRC.

One of the few studies reporting on SRC in youth female rugby players conducted by Cusimano et al (83) found that 52% of SRC occurred during the tackle. The lower percentage of SRC reported by Cusimano et al (83) may however be attributed to the fact that the study included players from five to 19 years old; thus, the variation in contact rules in younger players may have influenced the reported percentage. As the tackle resulted in the highest proportion of SRCs, future research should focus on identifying specific aspects of the tackle that increase the risk for sustaining a SRC in male and female youth rugby players.

SRC was more likely to occur during the tackle in boys U13 players when compared to boys U18 players. Poor tackling technique increases the risk of sustaining rugby injuries, including SRC (3, 58, 125, 129). A study conducted at the 2011-2013 U18 Craven Week Tournaments performed video-analysis of 10 SRCs that occurred at the tournaments (58). This study showed that SRC was more likely to occur if: the player in question was unaware of impending contact, their head was in a 'downwards' or 'away' position during the tackle; and 'leg-drive' by the tackler was absent (58). Therefore, together with the findings in this study it can be concluded there should be increased focus on teaching good and safe tackling technique in youth players, particularly in U13 boy players.

Currently, there is equivocal evidence regarding whether the ball-carrier or tackler is at a higher risk of sustaining a SRC in the tackle (84). Most recent evidence indicates that the tackler may be at a higher risk for sustaining a SRC (84). Previous research into South African youth rugby found a four-fold increased risk of the tackler sustaining than the ball-carrier. In contrast, this study found that the ball-carrier sustained 63% of all SRC sustained in the tackle. However, only 42% of tackle events recorded whether the concussed player was tackler or ball-carrier. These results should therefore be interpreted with some caution. Unfortunately, due to this low percentage of recorded SRCs identifying tackler/ball-carrier, it was not possible to analyse the data in depth to determine whether there were age group or sex differences.

The ruck was the second most common injury event resulting in SRC. The ruck accounted for 20% of all SRCs. The ruck was responsible for 16% of SRCs in girls and 21% of SRCs in boys. These findings are similar to a previous study which found that the ruck was responsible for 24% of SRCs in male South African youth players (82). There were no differences in SRC associated with the ruck between male and female groups. This suggests that injury prevention strategies addressing the ruck would be equally effective amongst youth male and female players. However, there was a difference in SRC incidence occurring in the ruck when comparing U16 boy player to U18 boy players. It thus may be useful for future research to focus on identifying the exact mechanism of injury for U16 boys in the ruck. Teaching of good contact technique in the ruck should also be addressed among all players, particularly boys U16 players.

Sport-related Concussion Mechanism of Injury

The most common SRC mechanisms of injury were front-on tackles (27%) and collisions (18%). The results from this study indicate that mechanism of SRC is similar between male and female youth players. Understanding injury mechanism is one of the crucial steps of the van Mechelen injury prevention model (31) and Finch's TRIPP model (32). As such it can be assumed that injury prevention programmes addressing mechanism of injury could be similar amongst boys and girls. SRC was more likely to occur due to collisions in U13 boys than U18 boys. SRC was similarly more likely to occur in U16 boys due to a collision than U18 boys. This might suggest that U13 and U16 boys need to be trained to avoid collisions. Previous studies have identified that in most SRC events the concussed player was not aware of impending contact (58). It is suggested that when a player is aware of impending contact, they are able to activate their cervical muscles and thus dissipate force sustained to the head in the concussive event. It thus stands to reason that teaching players to be more aware of their surroundings and to anticipate impending contact may be an effective SRC prevention strategy (58, 131). Teaching players to be aware of their surroundings at all times may also assist in avoiding collisions (58) .

U16 boys were more likely to sustain a SRC in a front-on tackle than U18 boys. Front-on tackles have been previously recognised as the tackle type resulting in the most SRC across various age groups. (4, 58, 127). In this study front-on tackles were responsible for the majority of injuries in most age groups. It may thus be suggested that the front-on tackle be one of the main contact events concentrated on when teaching safe contact technique. The results from this study further suggest that the U16 boy players may require particular attention when training this tackle type. Further research is however required to identify what aspects of the front-on tackle put players, particularly U16 boy players at risk for SRC.

This study also found that 7% of SRC occurred due to foul play. There were no significant differences between age groups and sexes. The majority of foul play events resulting in SRC were high tackles (82%). Further this study showed that overall only 39% of foul play events resulted in appropriate action from the referee. Previous studies have shown that 7% (4) and 41% (130) of illegal tackles were appropriately sanctioned in male adult elite level rugby and boys youth community rugby respectively. Although not evaluated in this study it stands to reason that players will be less likely to engage in foul play if they know they will be penalised by the referee. It has been previously stated that referees play an important role in injury prevention by penalising dangerous tackles (4, 130). Referees thus need to be taught to consistently penalise players for engaging in foul play. Further research should further focus on identifying why referees do not always penalise players for engaging in illegal play.

Factors Associated with Sport-related Concussion

Match day in the tournament and use of headgear were associated with the development of SRC. The majority of SRCs occurred on day one (26%) and two (27%) of the tournaments. The least SRC occurred on day six where only 1% of SRC occurred. These results contradicted what was expected, based on studies that showed an increased injury and SRC risk due to increased player fatigue and subsequent deterioration in contact technique (81, 82, 84). An alternative explanation is that players may have been less likely to report an injury on the last day of the tournament (36).

It is also possible that as the tournament progressed and as players fatigued, they were less likely to engage in the type of play that may result in a SRC. Players who were more likely to engage in reckless behaviour at the beginning of the tournament may also have been less likely to do so at the end of the tournament as they became fatigued. Further research should focus on investigating the effect of fatigue on SRC incidence over multiple day tournaments.

Players who did not wear headgear were more likely to sustain a SRC than those players that did. This finding contradicts previous studies which found that wearing headgear either had no effect on the incidence of SRC (135, 136, 154) or increased the risk of SRC (138). It could be theorised that players who wore headgear were less likely to engage in risky behaviour that may result in a SRC (86). Further research however is required to confirm these findings. Future research should focus on investigating why players who wear headgear may be less likely to sustain a SRC. The wearing of a mouth guards had no effect on the development of SRC, which is similar to the findings of Emery et al (134).

Management of Sport-related Concussion

This study found that 86% of players were immediately removed from play after sustaining a SRC, whereas 14% continued to play. This is concerning as current World Rugby laws (1) and guidelines from the 2016, Berlin Consensus Statement on SRC in Sport (66) state that any player who is suspected of having a SRC should be removed from play immediately. According to these guidelines, a player that has been removed from field for SRC evaluation may not return to play on that day whether or not a SRC is diagnosed (66). Unfortunately, this study was not designed to determine why 14% of concussed players were allowed to continue playing. Further research should thus focus on identifying these reasons to ensure that in the future every concussed player is removed promptly from the field of play. This study also indicates that increased focus needs to be placed on educating stakeholders regarding the risks of continuing to play with a SRC.

According to World Rugby and the South African Rugby Union players under the age of 18 may begin the graduated-return-to-sport protocol a minimum of two weeks after the SRC (99). The graduated-return-to-sport protocol will take players a minimum of four days to complete (18, 66, 69). Thus, players should only return to play at the earliest 19 days after having sustained the SRC. In this study 53% of players returned to play before 19 days. This is concerning as players, particularly youth players, stand a higher chance of sustaining a subsequent SRC or developing SRC complications when returning to sport too early (68, 69) . In future there should be Increased focus on educating players, coaches and referees on the risks of returning to play too early.

Study Limitations

The data collected were collected during week long tournaments. It is likely the incidence and mechanisms of injury reported by this study may thus be different to what may be found in regular rugby seasons, where a maximum of one game a week is usually played. The results of this study may only be generalisable to the tournaments at which the data were collected. The study can therefore only comment on SRC of elite youth players. Further research needs to be conducted to confirm these findings in school and community level youth rugby. Another limitation of the study is that the sample size for females was small. The female South African Youth Week Rugby Tournaments only started in 2015, thus female data could only be collected from this point in time. Research in the future should aim to confirm and elaborate on findings made by this study, particularly amongst female players. A further limitation to the study is that as the researcher was located in a tent and not pitchside it would be up to players and coaching staff to report possible SRCs that were not immediately noticeable by pitchside medical staff. Players and coaching staff may have been less inclined to report possible SRCs as they player would miss out on the rest of the tournament. Underreporting of SRC by players is a widely documented phenomenon (18, 19). SRC thus may have been underestimated.

4.2 Conclusion

Overall SRC incidence at the 2011 to 2018 South African Rugby Union Youth Week Tournaments was 7.0 SRC per 1000 match playing hours. Overall SRC incidence for male players was 6.9 SRC per 1000 match playing hours; and overall SRC incidence for female players was 7.6 SRC per 1000 match playing hours. This study is unique as it is the first of its kind to specifically report SRC incidence in female youth players. It is further the first study to report SRC incidence in South African youth female players. The incidence of SRC incidence was not different between male and female players.

SRC incidence for boys U13, U16 and U18 groups was 10.7, 7.5 and 5.5 SRC per 1000 match playing hours respectively. SRC incidence for girls U16 and U18 groups was 7.2 and 7.9 SRC per 1000 match playing hours respectively. U13 boys had a significantly higher incidence of SRC than U18 boys. Poorer contact technique and motor co-ordination in younger players may explain this finding (82).

The most common injury event resulting in SRC was the tackle and the ruck. U16 boys were at particular risk of sustaining a SRC in the ruck when compared to U18 boy players. U13 boys had a higher risk of sustaining a SRC in the tackle than U18 boys. The most common primary mechanisms of SRC were the front-on tackle and collisions. U13 and U16 boys were more susceptible to SRC in the collision than U18 boys. U16 boys were more susceptible to sustaining a SRC in the front-on tackle than U18 boys.

Additionally, this study found that found that SRC was more likely to occur on day one and two of the tournaments. Players who did not wear headgear were also more likely to sustain a SRC. Further research however is required to confirm these findings and establish why players who did not wear headgear were more susceptible to SRC.

According to Van Mechelen (31) and Finch (32) injury incidence and mechanism of injury must be known before an effective injury prevention programme can be completed (31). As the SRC incidence, injury event and primary mechanism of injury were the same between male and female youth players, it stands to reason that the same injury prevention strategies could be effectively implemented between male and female youth players. Injury prevention strategies should focus on teaching safe contact technique in the tackle and the ruck. Injury prevention programmes should pay particular attention to U13 boy players as SRC incidence was highest in this group. Injury prevention programmes should further specifically focus on teaching safe contact technique in the ruck and during front-on tackles to U16 boy players and teaching U13 boy players how to avoid collisions and tackle safely. Further research should focus on identifying what aspects of the tackle and ruck result in SRC, so that more targeted injury prevention programmes may be developed.

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Appendices

Appendix I: Human Research Ethics Committee Letter

UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee

Room E53-46 Old Main Building
Groote Schuur Hospital
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Telephone [021] 406 6492
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28 November 2018

HREC REF: 767/2018

Prof M Lambert
Division of Exercise Science & Sports Medicine
SSISA
Newlands

Dear Prof Lambert

PROJECT TITLE: CONCUSSION INCIDENCE AND MECHANISM OF INJURY IN MALE AND FEMALE PLAYERS AT THE SOUTH AFRICAN YOUTH WEEK RUGBY TOURNAMENT: 2011-2018 (MSc Candidate - Ms S Cardis)

Thank you for submitting your study to the Faculty of Health Sciences Human Research Ethics Committee (HREC) for review.

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study.

Approval is granted for one year until the 30 November 2019.

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.
(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

We acknowledge that the student: Miss Sheenagh Cardis will also be involved in this study.

Please quote the HREC REF in all your correspondence.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please note that for all studies approved by the HREC, the principal investigator **must** obtain appropriate institutional approval, where necessary, before the research may occur.

Yours sincerely

PROFESSOR M BLOCKMAN
CHAIRPERSON, FHS HUMAN RESEARCH ETHICS COMMITTEE

Federal Wide Assurance Number: FWA00001637.

This serves to confirm that the University of Cape Town Human Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical Research Council (MRC-SA), Food and Drug Administration (FDA-USA), International Convention on Harmonisation Good Clinical Practice (ICH GCP), South African Good Clinical Practice Guidelines (DoH 2006), based on the Association of the British Pharmaceutical Industry Guidelines (ABPI), and Declaration of Helsinki (2013) guidelines.
The Human Research Ethics Committee granting this approval is in compliance with the ICH Harmonised Tripartite Guidelines E6: Note for Guidance on Good Clinical Practice (CPMP/ICH/135/95) and FDA Code Federal Regulation Part 50, 56 and 312.

Appendix II: Data Collection Sheet

	ID	
Tournament Information	**Year**	
	Tournament	
Player Demographics	**Date of birth (yyyy-mm-dd)**	
	Age	
	Height (cm)	
	Weight (kg)	
	Ethnicity	
	Injury date (yyyy-mm-dd)	
	Tournament day	
	Union	
	Medical aid (yes/no)	
	Position group (centre/loose-forward/prop/wing/hooker /fullback/lock/fly-half/scrum-half)	
	Forward/Back	
	Position years	
Mechanism of Injury	**Match quarter (1st/2cnd/3rd/4th)**	
	Match status (started/substituted)	
	Match decision (discontinued/continued)	
	Injury event	
	Tackler/Ball Carrier	
	Injury location 1	
	Type of Injury	
	Injury mechanism 1	

	High/regulation/low tackle	
	Secondary injury mechanism	
	High/regulation/low tackle	
	Foul play? (Yes/no)	
	Foul play- elaborate	
	Foul play referee action? (yes/no)	
Injury information	**Injury nature 1 (new/old injury)**	
	Injury definition- after 1st assessment (medical attention/time-loss)	
	Confirmed injury definition 1- after follow-up (medical attention/time-loss)	
	End injury date (yyyy/mm/dd)	
	Number of missed days	
Protective Equipment	**Mouth guard**	
	Headgear	