

The Effectiveness and Implementation of the BokSmart *Safe Six* Injury Prevention Programme

Thesis Presented for the Degree of
DOCTOR OF PHILOSOPHY
in the Department of Human Biology
UNIVERSITY OF CAPE TOWN
June 2018

PhD Candidate

Nicola Ann Sewry (SWRNIC009)

Supervisors

Prof Willem Van Mechelen (VU University Medical Center, Amsterdam)

Prof Mike Lambert (UCT)

Prof Evert Verhagen (VU University Medical Center, Amsterdam)

Dr James Brown (UCT/Stellenbosch University)

The copyright of this thesis vests in the author. No quotation from it or information derived from it is to be published without full acknowledgement of the source. The thesis is to be used for private study or non-commercial research purposes only.

Published by the University of Cape Town (UCT) in terms of the non-exclusive license granted to UCT by the author.

Acknowledgements

Many people ask me the question “So, how many years of PhD has been it now? The truth is, I think they often forget it is more than just the three years you register for a PhD, it’s your whole education that leads up to that, resulting in a large group of people I want to thank in getting me to where I am today.

Firstly, to the **Desmond Tutu Doctoral Programme, National Research Foundation** and the **South Africa Vrije Universiteit Strategic Alliance (SAVUSA)** thank you for affording me the opportunity to complete a joint PhD with VUmc.

To all my friends (school, university and other) for the constant support and questions regarding how the PhD was going, even when you never really knew what was going on, I have always appreciated the interest in my studies.

To the UCT rugby club, Ikeys, the times I have had with the management of the U20 team, have been unforgettable. The lessons I have learned from **Tom, Laura, Craig, Dave** and **Josh** (the best management team I’ve ever worked with) will stick with me forever. Tom, you led the team with a spirit unmatched, and taught me so much about myself and what I am capable of, and I thank you for this. #ABW

To the support staff at ESSM: **Ayesha, Lesa, Ashleen, Trevino** and **Nezaam**, you all make everything involved with studying at ESSM that much simpler.

To all the friends I made in The Netherlands: **Joske, Femke, Saulo, Caroline, Roland, Anne, Saskia, Ingrid, Nici, Stefan**. The lunch dates, SLH weekend away trip, SLH drinks and teaching me the Dutch ways of Sinterklaas and all things Dutch, it has been a great education in international living.

The completion of the cRCT was a huge undertaking (one that changed in day due to unforeseen circumstances), and therefore a huge thank you must go to all involved. To all the testers who worked for the project during those 18 weeks, you will never know how you saved my PhD by dedicating your afternoons to testing schools across the province. To the schools and coaches involved, thank you for your cooperation and enthusiasm with the project. For the other chapters, thank you to the coaches and players who completed questionnaires and agreed to share their injury data with SA Rugby and my project. To the data collectors and medical staff at the youth weeks, thank you for your effort and brilliant data recording.

Thanks must also go to some special people at ESSM. I have been at ESSM for six years now and some very good friends have been made. To all the friends and colleagues from both ESSM and SSISA over the years, thank you for your friendship and good times. Then, to two very good friends of mine: **Sam** and **Marelise**. You two have been my pillars throughout this journey, and I cannot wait to see you two hand-in. Marelise, having someone go through the exact experiences I was, was the best. You were the one I could always call from Amsterdam if I was having a rough day, because I knew you would understand. Thank you both for everything along the way, I would not be here without your support throughout the years.

Now for the supervisors, I was lucky enough to have four supervisors (Mike, Willem, Evert and James), as well as two advisors (Clint and Wayne) and Jos who assisted on a paper.

Jos – thank you for your assistance in the statistical side, you added much value to our paper and taught me lots.

Clint and Wayne – SA Rugby and BokSmart have played a large role in my time at ESSM. Clint and Wayne are the reasons I have been able to complete this PhD. Clint, you have provided me with incredible opportunities such as working at the World Sevens Series in Port Elizabeth, whilst Wayne, I have learnt so much about research and implementing it from a stakeholders perspective. The two of you make a great team, and I am honoured to have been a part of that team. The access to the data, and the questions we have asked along the way through this PhD are largely owed to the both of you. My passion had always been for rugby, but working with both of you have made me realise just how big an impact research can make in rugby and how much further we still have to go in the area. Thank you for trusting me with this project Wayne, I know how much you have invested into the *Safe Six* and I have thoroughly enjoyed working with you.

Mike – my supervisor since I arrived in 2012, you have made me into the researcher I am today. You fought hard to get me onto the Desmond Tutu bursary, to ensure we had the funding to complete the cRCT, and never were these issues too big or small for you to solve. I told you from the moment I arrived at ESSM that I wanted to work in rugby, and the first thing you did was introduce me to Clint. You managed to get me extra work with SA Rugby and foster a relationship with BokSmart and SA Rugby for the future. Mike, you have helped me get to where I am today, and I could not have asked for a better supervisor throughout my time in Cape Town.

Willem – you are the epitome of an accomplished researcher, and having you as a supervisor has been an honour. Thank you for all the effort you went to get me onto the bursary, it has been great fun being able to travel and learn from international researchers. Thank you for being the supervisor you are and teaching me about enjoying life to the fullest!

Evert – you have been an incredible source of reason with every step in this process. It's been great fun along the way: mountain biking, picnics at Cape Point Vineyards, SLH weekend away in The Netherlands. Thanks for helping me produce the best quality research I could.

James – three years ago you started a post-doc and landed up with two PhD students. Not sure if that was by choice, but regardless, you have been a remarkable supervisor with the most entertaining comments on drafts. I will never forget when you commented on my paper asking if I was writing for YOU magazine? You managed to bring humour to shocking writing, and encouragement when it felt like dire straits. Trips to the Creamery definitely made us gain weight, but was the best tradition ever instilled, and I will definitely be joining in celebrating future accomplishments. You have taught me about academics, research, life, and honestly, we have had a jol! Thank you for everything over the three years, it has been a privilege to be your student.

On a more personal note, **Jarred**, you have been by my side throughout my MSc and PhD. You might have been far away during the last 4 years, but you have been my support throughout it all. Thank you for understanding why I needed to do this and stay in Cape Town. I look forward to us finally moving to the same city and seeing where it takes us. Thank you for your patience, we are finally at the finish line!

Finally, to the three people who have been there since the beginning of it all: **Chris, Mom and Dad**. First off to Chris, thanks for sort of knowing what I have been doing all this time, something along the lines of “Dr Rugby” as you like to refer to it as, it has been great having you be a part of it, always your little sister! To Mom and Dad, thank you for making this all possible, you have financially supported me all these years and I will be forever grateful. Dad, you are the reason I always knew I wanted to do my PhD, you have been the one who has shaped me into the academic I am. You prepared me for this my whole life without knowing it, and I love that we have that in common and discussing academic dilemmas with you is my favourite pastime. Mom, you have been my voice of reason all these years when things have gotten too much, you have always been there for me, and if I can ever be half the teacher you are, I will know I have succeeded.

Personal Funding for this PhD was provided by:

- National Research Foundation, through their Desmond Tutu Doctoral Training Programme and the South Africa Vrije Universiteit Strategic Alliance (SAVUSA)
- University of Cape Town
- Oppenheimer Memorial Trust
- Zuid-Afrika Huis Studiefons

Declaration of Inclusion of Publications

I confirm that I have been granted permission by the University of Cape Town's Doctoral Degrees Board to include the following publication(s) in my PhD thesis, and where co-authorship are involved, my co-authors have agreed that I may include the publication(s):

Sewry, Verhagen, Lambert, van Mechelen, Marsh, Readhead, Viljoen, Brown. Trends in time-loss injuries during the 2011-2016 South African Rugby Youth weeks. *Scandinavian Journal of Medicine and Science in Sports*. 2018. **Accepted (Chapter 2)**

Sewry, Verhagen, Lambert, van Mechelen, Viljoen, Readhead, Brown. Exercise-Based Interventions for Injury Prevention in Tackle Collision Ball Sports: A Systematic Review. *Sports Medicine*, 2017;47(9): 1847-1857 **Published (Chapter 3)**

Sewry, Verhagen, Lambert, van Mechelen, Brown. Players' and coaches' knowledge and awareness of the BokSmart Safe Six injury prevention programme: an ecological cross-sectional questionnaire study. *BMJ Open*, 2017;7:e018575 **Published (Chapter 4)**

Sewry, Verhagen, Lambert, van Mechelen, Brown. Evaluation of the Effectiveness and Implementation of the BokSmart Safe Six Injury Prevention Programme: a study protocol. *Injury Prevention*, 2017;23:428 **Published (Chapter 6)**

Sewry, Verhagen, Lambert, van Mechelen, Readhead, Viljoen, Brown. Seasonal injury rates and burden in three South African under-16 schoolboy teams. *Journal of Science and Medicine in Sport*. 2018 **Submitted, in review (Chapter 7)**

Student Name: Nicola Ann Sewry

Student Number: SWRNIC009

Signature:

Signed by candidate

Date: 20/06/2018

Plagiarism Declaration

“This thesis/dissertation has been submitted to the Turnitin module (or equivalent similarity and originality checking software) and I confirm that my supervisor has seen my report and any concerns revealed by such have been resolved with my supervisor.”

Name: Nicola Ann Sewry

Student number: SWRNIC009

Signature:

Signed by candidate

Date: 20/06/2018

Abstract

INTRODUCTION: Injury prevention programmes in rugby union are important to reduce the sport's injury burden. The BokSmart *Safe Six* exercise-based injury prevention programme ("*Safe Six*") was designed for this purpose. The programme incorporates six targeted exercises as a warm-up for rugby players. The effectiveness of the BokSmart *Safe Six* programme was assessed using the "Sequence of Prevention" Model.

METHODS: The first study was a prospective cohort study using injury surveillance, of players at the South African Rugby (SA Rugby) Youth week tournaments. The study was conducted over six years to determine the injury incidence density (IID) youth players and also factors associated with the IID. The second study was a systematic review with the purpose of determining the effectiveness of exercise-based injury prevention interventions to reduce injury rates in collision sports. The next study was conducted over three years of SA Rugby Youth weeks and assessed the awareness of coaches and players of the BokSmart *Safe Six* following a targeted-marketing approach. This was followed by a study in which the BokSmart *Safe Six* programme was implemented in a cohort of apparently healthy non-rugby playing adults. The aim of this study was to determine the efficacy of the programme on injury risk profiles (Functional Movement Screening and Musculoskeletal Screening Assessments). The final study was a cluster-randomised controlled trial (cRCT) over eight weeks, using six schools (n = 210 players) in the Western Cape to determine the effectiveness of the BokSmart *Safe Six* on injury risk profiles and IID.

RESULTS AND CONCLUSIONS: SA youth rugby cohort have a similar IID to other youth rugby cohorts (and in some instances lower). The systematic review identified only one high-level study (out of three) that was effective for injury prevention. The players' awareness of the BokSmart *Safe Six* was associated with the awareness of their specific coaches' awareness. The awareness increased during the targeted marketing approach. The BokSmart *Safe Six* was associated with minimal significant improvements of the injury risk profiles in both the healthy adults and in the cRCT intervention group youth rugby players.

Table of Contents

Introduction.....	10
Trends in time-loss injuries during the 2011-2016 South African Rugby Youth Weeks.....	22
Exercise-based interventions for injury prevention in tackle collision ball sports: a systematic review.....	41
Players’ and coaches’ knowledge and awareness of the BokSmart <i>Safe Six</i> injury prevention programme: an ecological cross-sectional questionnaire study.....	60
Efficacy of the BokSmart <i>Safe Six</i> injury prevention programme on injury risk profiles in healthy adults; a pilot study.	74
Evaluation of the effectiveness and implementation of the BokSmart <i>Safe Six</i> injury prevention program: a study protocol	87
Seasonal match injury rates and burden in three South African under-16 schoolboy teams.	106
Effectiveness of the BokSmart <i>Safe Six</i> exercise programme on injury rates and injury risk profiles of under-16 male rugby players	119
General Discussion	135
Appendices.....	150

CHAPTER 1:
INTRODUCTION

Background

Rugby Union (hence referred to as ‘rugby’) is an international sport played in over 100 countries worldwide at professional and amateur levels. Rugby is particularly popular in South Africa, with over 468 000 players in 2016.[1, 2] In 1995 rugby became professional, increasing resulting in an increase in the number of individuals participating in the sport.[3] Each rugby team consists of fifteen players, made up of varying positions, broadly grouped into two categories: eight forwards (number 1 – 8) and seven backs (numbers 9 – 15). Although these different positions are associated with varying anthropometric and physiological demands,[3-8] the injury incidence and types of injuries are not different between forwards and backs.[9]

One major characteristic of rugby is that of the tackle, a bodily collision that is the most effective and legal way to stop the opposing team from scoring points, and as such gaining competitive advantage.[10] The tackle is the most frequently executed manoeuvre in rugby and is defined by “when a ball carrier is contacted (hit and/or held) by an opponent, without reference to whether they went to the ground”.[11] Considering that the tackle is a ballistic and high force/momentum-generating manoeuvre, this aspect of play is associated with a high risk for injury and requires a large amount of skill to ensure it is performed safely and effectively.[12] Other major facets of play include the scrum and the line-outs, both of which include the forward players only. The scrum is also associated with a high injury risk as it is a force-producing set piece, and over the years the laws surrounding the scrum have changed numerous times in an attempt to make the scrum safer, including much development in the scrum engagement laws (for example PreBind).[13, 14] With these varying phases of play and set pieces within the sport, the physiological and psychological demands on a player are large, and if the player is not properly prepared, the risk of sustaining an injury will be high.

The “Sequence of Prevention” model is often applied to understand the magnitude, severity and aetiology of injuries in rugby, and to develop safety programs to prevent injuries in rugby (Figure 1.1).[9, 15, 16] The model describes four steps in the process towards successful injury prevention; (1) the identification and description of the extent of the injury problem within the sport; (2) the factors and mechanisms which contribute to the occurrence of the injuries within the sport; (3) the introduction of preventative measures which are likely to reduce the future risk and/or severity of the injuries; and (4) the evaluation of the effects of the preventative measures in step three by performing step one again.[15] The next few sections will describe these four steps in the context of rugby.

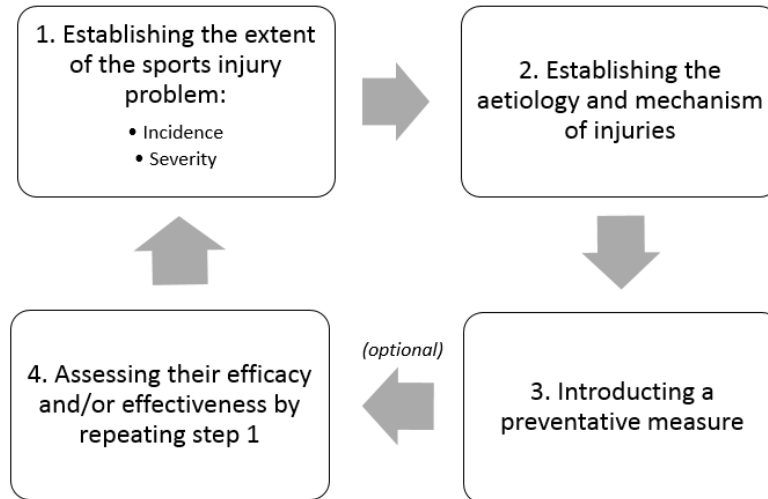


Figure 1.1: “Sequence of Prevention” model.

Step 1) The identification and description of the extent of the of the injury problem within the sport

In 2007, a consensus statement standardized the reporting of injury data within rugby ensuring future data defined according to these criteria would be comparable.[17] According to the consensus statement, for reporting reasons, the operational definition of an injury can be categorised into two different types: 1) a medical attention injury, which is defined as “an injury that results in a player receiving medical attention”, or 2) a time-loss injury defined as “an injury that results in a player being unable to take a full part in future rugby training or match play”.[17] The consensus statement makes the point that time-loss injuries are more comparable between studies, and therefore, hereinafter a time-loss injury will be referred to as an “injury”. The extent of the injury problem in rugby has been investigated and a meta-analysis found the overall injury incidence density in senior rugby players to be 81 (95% CI 63 – 105) injuries per 1,000 player match hours and 3 (95% CI 2 – 4) injuries per 1,000 player training hours. [9] Going forward, only match injuries will be discussed. Whilst the training injury incidence is low, the incidence of injuries within a rugby match is high in comparison to other sports. For example, in men’s collegiate (senior) soccer in the United States a total of 19 injuries per 1,000 player hours was reported (this definition of injury is a game injury “an injury that required medical attention and resulted in at least one day of time loss”),[18] much lower than that in rugby. Furthermore, in youth rugby within the South African context, the average injury incidence was 23 injuries per 1,000 player hours across age group tournaments, which is still higher than that in collegiate soccer (19 injuries per 1,000 player hours).[19] It must be noted

that the competitive nature of a tournament could alter the medical decision on a player missing further days to ensure a player can participate in important games. Other youth cohorts (over a season) have reported an injury incidence of between 24 – 35 injuries per 1000 player hours, therefore showing that youth rugby also has a high injury incidence.[20-23]

The types of injuries most commonly occurring at senior level rugby were muscle/tendon injuries at 40 injuries per 1,000 player hours, and joint (non-bone)/ligament at 34 injuries per 1,000 player hours.[9] Besides being the most commonly occurring, these soft-tissue injuries are also regarded as *preventable* injuries,[24] thus providing scope for a preventive intervention to decrease the incidence of injury. Most of the injuries occurred in the lower limbs, followed by the upper limbs, head and lastly the trunk in adults (results from a meta-analysis).[9] A youth systematic review has been conducted, however, it includes up to the ages of 21, and therefore youth cohort studies were preferred when drawing comparisons.[25] In youth rugby cohort studies, similar injury types are common, however, the injury incidence is lower, and central and peripheral nervous system (CNS/PNS) injuries are also common.[20, 22] When using severity of injury (time lost from training and competition) as the measure in seniors, the lower limb remains the most severely injured body part, with trunk next, followed by the head/neck area (the upper limbs were not reported on).[9]

Following the “Sequence of Prevention”, the phases of play (activities performing when injured) when the injuries occur need to be described before the mechanisms of injury can be investigated. The tackle is the largest contributor to injuries, with an average incidence of 29 injuries per 1000 player hours for the ball-carrier (i.e. player getting tackled); this incidence is lower for the tackler, 19 injuries per 1000 player hours.[9, 10, 19, 26-30] The ruck is the second highest after the tackle situation, with 17 injuries per 1000 player hours, followed by collisions (11 per 1000 player hours), scrums (7 per 1000 player hours), other (6 per 1000 player hours) and lineouts (1 per 1000 player hours) in seniors.[9] For youth cohorts, the tackle is still the largest contributor, with an injury incidence of 10 injuries per 1000 player hours and 8 injuries per 1000 player hours for the tackler.[23] These values should be interpreted with caution because the phases of play are presented as “per 1000 player hours” and do not account for the percentage of time spent performing these activities during a match. For example, a greater percentage of time is spent tackling or being tackled compared to scrumming.[3]

The severity of injuries in senior rugby has been thoroughly investigated. In senior rugby, “moderate” injuries (defined as 8 – 28 days lost from training) are most common, and when

specific days lost have been reported the mean for a match injury is 20 days lost per 1000 player hours.[9] In youth rugby, a study reported that almost half (49%) of injuries over a season were classified as “severe” (>28 days lost from training).[20] Another study showed the injury burden was 862 days lost per 1000 match player hours,[22] illustrating a higher injury severity in the youth than the seniors.

Using the information from the first step in the “Sequence of Prevention” (incidence and severity of injuries), injury prevention programmes in rugby should focus on muscle/tendon, joint (non-bone)/ligament in both youth and seniors, and CNS/PNS injuries, particularly in the youth.

Step 2) The factors and mechanisms that contribute to the occurrence of the injuries within the sport

The second step of the “Sequence of Prevention” examines the aetiological factors and mechanisms causing the injuries.[10] As described earlier, the various phases of play during the game demand different skill sets and physiological systems and therefore the number of injuries occurring within them are vastly different. The tackle (both ball-carrier and tackler) has the highest injury incidence of all the phases of play, and therefore the mechanisms underlying this phase of play are of particular interest. Players’ technique during the tackle (both tacklers and ball-carriers) is associated with risk of injury. For example, for ball-carriers, using a fend and being aware of the impending contact, have been associated with decreased injury risk.[31]

For tacklers, technique plays a role in injury risk as well. A preferable head position (to the side of the tackle) when contact occurs has also been associated with a decreased injury risk in the tackle situation.[32] In addition to the player’s technique, the type of tackle can influence the risk of injury; shoulder tackles are less likely to result in injury compared to an arm tackle (per event).[31] Since the tackle is the most commonly occurring phase of play,[3] and has a high energy expenditure, the development of fatigue as the game progresses may compromise the technique leading to injury. In summary, players have a risk of injury because of the contact nature of the sport, and through both conditioning and correct technique, injury incidences could potentially be decreased. However, it must be noted that some injuries as a result of collisions are unavoidable, independent of conditioning and skill.

Step 3) The introduction of preventative measures which are likely to reduce the future incidence and/or severity of the injuries

The large injury incidence and severity of injuries in both senior and youth rugby shows the need for injury prevention strategies.[29] As a consequence intervention programmes have been developed in the major rugby playing countries. For example, Australia has SmartRugby, New Zealand has RugbySmart and South Africa has BokSmart. [16, 33, 34] These programmes have been designed to reduce injuries in rugby, particularly serious catastrophic injuries. RugbySmart specifically, was associated with a decrease in disabling spinal cord injuries in scrums following the educational initiative.[35] The focus will now be on South Africa's BokSmart programme.

BokSmart

The BokSmart programme (adapted from the precursor RugbySmart of New Zealand) [16] was launched in South Africa in July 2009 and has four main components: 1) the compulsory BokSmart Rugby Safety biennial workshops designed for coaches and referees; 2) the BokSmart rugby Medic programme, a basic first aid course aimed at the lower level/underprivileged schools and clubs to ensure the safety of the players; 3) the toll-free BokSmart SpineLine, telephone number available for all head/neck and spine injuries to assist in getting the injured players to the nearest and best medical facility in the quickest time; and 4) the online website (www.boksmart.com) that covers issues about rugby safety – the resources are freely available.[16] BokSmart's distributed material is evidence-based, as much as possible.[16] Historically, BokSmart's primary focus was safe technique and education of referees and coaches around the risk of rugby and how to decrease that risk. BokSmart includes mandatory biennial courses for coaches and referees of coaches at all levels.[16, 36] The BokSmart programme is implemented and continually improved and new aspects added. BokSmart attempts to address the injury incidence and severity in South African rugby, by using the information gathered in the previous two steps, by specifically targeting scrum and tackle technique.

Step 4) The evaluation of the effects of the preventative measures, the repetition of step 1

BokSmart has begun to evaluate the overall BokSmart rugby safety programme, however, presently there is minimal data available.[37, 38] BokSmart has performed injury surveillance at the South Africa Youth Week tournaments, as well as nationwide data collection of catastrophic injuries (in conjunction with the Chris Burger/Petro Jackson Players Fund) and assessments of player's knowledge/attitudes/behaviours towards injury prevention strategies.[19, 37, 38] The BokSmart programme has been associated with significant improvements in players' injury-preventing behaviours,[37] which will hopefully lead to a decrease in the injury incidence and severity within South Africa. Furthermore, the BokSmart programme has been associated with a reduction in catastrophic injuries in youth players in South Africa,[38] but has not been assessed for its effect on general (non-catastrophic) injuries. Although the BokSmart programme has addressed technique and medical support, it has not focussed on the connection between specific skill, strength and motor control training to fully address the injury aetiology. This final connection was highlighted by World Rugby and further initiated by BokSmart. The final step in the "Sequence of Prevention" re-assesses the injury incidence to determine if the BokSmart programme is effective. The final step is important to provide information that can improve the BokSmart programme as an evolving injury prevention national safety programme.

Development of effective exercise-based injury prevention programmes

Based on the high injury risk and available evidence of injury risk factors, World Rugby (the sport's international organization) challenged all national rugby unions to develop an exercise-based intervention to reduce injury incidence rates within the game. Exercise-based interventions are hypothesized to elicit favourable changes in neuromuscular function, motor control and range of motion.[24] These changes are then assumed to decrease injuries in sports. Intermediary measures of injury, such as the Functional Movement Screening, have also been shown to be affected by exercise-based interventions through the changes in motor control and range of motion.[39] Exercise-based injury prevention programmes have been effective in other non-collision sports, such as ankle stability training in volleyball,[40] and the more recent developments in football with the FIFA 11+ programme.[41] In response to World Rugby's challenge, BokSmart (and thus the South African Rugby Union) developed the *Safe Six* exercises. The *Safe Six* exercises were developed in conjunction with available data from research, and the clinical knowledge of professionals experienced in rugby injuries. The

exercises were chosen specifically to match the common sites of injury on rugby.[9] In accordance, the targeted areas of injury prevention were the knee, hamstring, lower limb, ankle and shoulder. The exercises were designed to increase strength, joint stability, balance and control, with the overall goal of reducing the rate and severity of injuries. This exercise-based intervention was launched in 2014 (Appendix I).

The exercises were designed to be included as part of the regular team warm-up. In particular, they were designed to optimise the implementation of these exercises, meaning that they can be performed without any equipment and are of short duration, so they would not interfere with regular training.

Thesis Outline

Seven research questions are described in this thesis to answer the larger research question on the effectiveness and implementation of the BokSmart *Safe Six* injury prevention programme. These chapters extend through all four steps of the “Sequence of Prevention” model, providing an overview of the youth rugby injury rates and severity of injuries, the aetiology of injuries, the development of an injury prevention programme, and finally the establishment of efficacy and effectiveness of the *Safe Six* programme.

Chapter 2 addresses the first and second steps of the “Sequence of Prevention”, establishing the extent of the injury problem in the specific youth rugby player population in South Africa and further investigating the aetiology and mechanisms of these injuries in their specific context. This chapter uses data from the SARU injury surveillance project at the annual youth week tournaments.

Chapter 3 explores the literature currently available for exercise-based interventions performed in collision sports, forming the basis for the BokSmart *Safe Six*. This study completes the third step of the “Sequence of Prevention”.

Following the launch of the BokSmart *Safe Six*, Chapter 4 uses three years of questionnaire data to determine the changes in knowledge and awareness of the injury prevention programme to investigate the knowledge dissemination of the BokSmart *Safe Six*.

Chapter 5 is an efficacy study, to determine the associations of the BokSmart *Safe Six* with injury risk profile changes (i.e. changes in FMS scores) in the non-rugby playing community, using the injury risk profiles as a proxy for injuries (thereby completing step four).

Chapter 6 – 8 describe the cluster-randomized controlled trial of the BokSmart *Safe Six* and its association with injury risk profiles and rates.

Chapter 9 – the overall Discussion – summarises all the studies performed from Chapter 2 – 8.

References

1. Meir R, Halliday A. Pre- and post-game body mass changes during an international rugby tournament: a practical perspective. *J Strength Cond Res.* 2005;713-16.
2. World Rugby. Year in Review 2016. 2016 [cited 2018 June 7]. <http://www.worldrugby.org/documents/annual-reports?lang=en>.
3. Duthie G, Pyne D, Hooper S. Applied physiology and game analysis of rugby union. *Sports Med.* 2003;973-91.
4. Gabbett T. Physiological and anthropometric characteristics of amateur rugby league players. *Br J Sports Med.* 2000;303-07.
5. Carlson B, Carter J, Patterson P, Petti K, Orfanos S, Noffal G. Physique and motor performance characteristics of US national rugby players. *J Sports Sci.* 1994;403-12.
6. Durandt J, Du Toit S, Borresen J, et al. Fitness and body composition profiling of elite junior South African rugby players. *S Afr J Sports Med.* 2006;38-45.
7. Quarrie K, Wilson B. Force production in the rugby union scrum. *J Sports Sci.* 2000;237-46.
8. Gabbett T, Jenkins D, Abernethy B. Relationships between physiological, anthropometrical and skill qualities and playing performance in professional rugby league players. *J Sports Sci.* 2011;1655-64.
9. Williams S, Trewartha G, Kemp S, Stokes K. A meta-analysis of injuries in senior men's professional Rugby Union. *Sports Med.* 2013;43(10):1043-55
10. Hendricks S, Lambert M. Tackling in rugby: coaching strategies for effective technique and injury prevention. *Int J Sports Sci Coach.* 2010;117-31.
11. Quarrie K, Hopkins W. Tackle injuries in professional rugby union. *Am J Sports Med.* 2008;1705-16.
12. Hendricks S, Karpul D, Lambert M. Momentum and kinetic energy during the tackle in rugby union. *J Sports Sci Med.* 2014;13(3):557-63.
13. Cazzola D, Preatoni E, Stokes K, et al. A modified prebind engagement process reduces biomechanical loading on front row players during scrummaging: a cross-sectional study of 11 elite teams. *Br J Sports Med.* 2015. 49(8):541-546.
14. Hendricks S, Lambert MI, Brown JC, Readhead C, Viljoen W. An evidence-driven approach to scrum law modifications in amateur rugby played in South Africa. *Br J Sports Med.* 2014;48(14):1115-19.
15. van Mechelen W, Hlobil H, Kemper HC. Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. *Sports Med.* 1992;14(2):82-99.
16. Viljoen W, Patricios J. BokSmart – implementing a National Rugby Safety Programme. *Br J Sports Med.* 2012;46(10):692-93.
17. Fuller C, Molloy M, Bagate C, et al. Concensus statement on injury definitions and data collection procedures for studies of injuries in rugby union. *Br J Sports Med.* 2007;328-31.
18. Hootman JM, Dick R, Agel J. Epidemiology of Collegiate Injuries for 15 Sports: Summary and Recommendations for Injury Prevention Initiatives. *J Athl Train.* 2007;42(2):311-19.
19. Brown J, Verhagen E, Viljoen W, et al. The incidence and severity of injuries at the 2011 South African Rugby Union (SARU) Youth Week tournaments. *S Afr J Sports Med.* 2012;49-54.
20. Archbold HAP, Rankin AT, Webb M, et al. RISUS study: Rugby Injury Surveillance in Ulster Schools. *Br J Sports Med.* 2017;51(7):600-06.
21. Haseler CM, Carmont MR, England M. The epidemiology of injuries in English youth community rugby union. *Br J Sports Med.* 2010;44(15):1093-99.

22. Hislop MD, Stokes KA, Williams S, et al. Reducing musculoskeletal injury and concussion risk in schoolboy rugby players with a pre-activity movement control exercise programme: a cluster randomised controlled trial. *Br J Sports Med.* 2017;51:1140-46.
23. Palmer-Green DS, Stokes KA, Fuller CW, England M, Kemp SPT, Trewartha G. Match injuries in English youth academy and schools Rugby Union: an epidemiological study. *Am J Sports Med.* 2013;41(4):749-55.
24. Andrew N, Gabbe BJ, Cook J, et al. Could targeted exercise programmes prevent lower limb injury in community Australian football? *Sports Med.* 2013;43(8):751-63.
25. Freitag A, Kirkwood G, Scharer S, Ofori-Asenso R, Pollock AM. Systematic review of rugby injuries in children and adolescents under 21 years. *Br J Sports Med.* 2015;49(8):511-19.
26. Brooks J, Fuller C, Kemp S, Reddin D. Epidemiology of injuries in English professional rugby union: part 1 match injuries: *Br J Sports Med.* 2005:757-66.
27. Brooks J, Fuller C, Kemp S, Reddin D. Epidemiology of injuries in English professional rugby union: part 2 training injuries. *Br J Sports Med.* 2005:767-75.
28. Brooks J, Kemp S. Recent trends in rugby union injuries. *Clin Sports Med.* 2008:51-73.
29. Burger N, Lambert MI, Viljoen W, Brown JC, Readhead C, Hendricks S. Tackle-related injury rates and nature of injuries in South African Youth Week tournament rugby union players (under-13 to under-18): an observational cohort study. *BMJ Open.* 2014;4(8).
30. Hendricks S, Matthews B, Roode B, Lambert M. Tackler characteristics associated with tackle performance in rugby union. *Eur J Sport Sci.* 2014:1-10.
31. Burger N, Lambert MI, Viljoen W, et al. Mechanisms and factors associated with tackle-related injuries in South African Youth Rugby Union players. *Am J Sports Med.* 2017;45(2):278-85.
32. Sobue S, Kawasaki T, Hasegawa Y, et al. Tackler's head position relative to the ball carrier is highly correlated with head and neck injuries in rugby. *Br J Sports Med.* 2017: doi: 10.1136/bjsports-2017-098135.
33. New Zealand Rugby Union. Technique: the key factors in the tackle and taking the ball into contact. *RugbySmart 2007: A guide to injury prevention for peak performance.* 2007:12-14.
34. Australian Rugby Union. Key points for the tackler and ball-carrier, *Australian Rugby Union SmartRugby: Confidence in contact. A guide to the SmartRugby Program.* 2008:18-19.
35. Quarrie KL, Gianotti SM, Hopkins WG, et al. Effect of nationwide injury prevention programme on serious spinal injuries in New Zealand rugby union: ecological study. *BMJ.* 2007;334(7604):1150.
36. Posthumus M, Viljoen W. BokSmart: safe and effective techniques in rugby union. *S Afr J Sports Med.* 2008:64-69.
37. Brown JC, Gardner-Lubbe S, Lambert MI, Van Mechelen W, Verhagen E. The BokSmart intervention programme is associated with improvements in injury prevention behaviours of rugby union players: an ecological cross-sectional study. *Inj Prev.* 2015;21(3):173-78.
38. Brown JC, Verhagen E, Knol D, Van Mechelen W, Lambert MI. The effectiveness of the nationwide BokSmart rugby injury prevention program on catastrophic injury rates. *Scand J Med Sci Sports.* 2016;26(2):221-25.
39. Bodden JG, Needham RA, Chockalingam N. The effect of an intervention program on Functional Movement Screen test scores in Mixed Martial Arts Athletes. *J Strength Cond Res.* 2015;29(1):219-25.
40. Verhagen E, Van der Beek A, Twisk J, Bouter L, Bahr R, Van Mechelen W. The effect of a proprioceptive balance board training program for the prevention of ankle sprains a prospective controlled trial. *Am J Sports Med.* 2004;32(6):1385-93.

41. Rössler R, Junge A, Bizzini M, et al. A Multinational Cluster Randomised Controlled Trial to Assess the Efficacy of '11+ Kids': A Warm-Up Programme to Prevent Injuries in Children's Football. *Sports Med.* 2017.

CHAPTER 2:

TRENDS IN TIME-LOSS INJURIES DURING THE 2011-2016 SOUTH AFRICAN RUGBY YOUTH WEEKS.

Published as:

Sewry, Verhagen, Lambert, van Mechelen, Marsh, Readhead, Viljoen, Brown. Trends in time-loss injuries during the 2011-2016 South African Rugby Youth weeks. *Scandinavian Journal of Medicine and Science in Sports*. 2018. **Accepted**

Abstract

Background

Youth rugby is a popular sport in South Africa (SA) with a high injury incidence. The annual SA Rugby Youth Week tournaments attract the top age group players in the country providing a sample of players for reliable injury surveillance. The primary aim of the study was to analyse the changes in time-loss injury rates at the SA Rugby Youth Week tournaments between 2011 and 2016, differences between age-groups, and to investigate associated injury risk factors.

Methods

All confirmed time-loss injuries at the four age group tournaments (under-13, under-16 and two under-18) from 2011–2016 were recorded. Injury incidence densities (IID) for years, tournaments and injury risk factors were calculated and Poisson regression analyses were performed to determine differences.

Results

Time-loss injuries (n=494) were reported over 24,240 exposure hours, with an overall IID of 20.4(18.6–22.2) injuries per 1000 player hours. 2013 had a significantly lower IID compared to 2011. Injury risk decreased with increasing age; under-13 and under-16 had significantly higher IID compared to under-18 Craven Week. Tackling was the phase of play at highest risk, with an IID of 7.4(6.3–8.5) injuries per 1000 player hours. Central/Peripheral Nervous System (CNS/PNS) and therefore, the Head/Neck were the most commonly occurring injuries/location injured.

Conclusion

Within the SA Rugby tournament structure, the older players had a decreased rate of injury. The tackle event was still the phase of play with the highest injury incidence regardless of age.

Introduction

Rugby union (hence referred to as ‘rugby’) is an international sport played in over 100 countries at professional and amateur levels and is particularly popular in South Africa, with over 468,000 players (as of 2016).[1, 2] Given the contact nature of rugby, the injury incidence is high. An injury incidence density (IID) of 81 (95%CI 63–105) injuries per 1000 match hours for time-loss injuries was recorded in senior professional players[3] and 71 (95%CI 60-85) injuries per 1000 player hours specifically in South African senior professional players.[4] In youth rugby, match time-loss IID appears to be lower, with 35 injuries per 1000 match hours (95%CI 29–41) reported in English youth competitions,[5] and 22 injuries per 1000 player hours (95%CI 20–25) in South African youth tournaments.[6] This injury incidence is higher than in other sports, such as collegiate soccer which has an incidence of 19 injuries per 1000 match hours.[7] Factors associated with the higher injury rates in rugby have been investigated in both youth and senior cohorts, indicating that the tackle causes the majority of injuries and lower limb injuries are the most prevalent injuries.[3, 8] However, due to limited data, further investigation is required in youth cohorts.

This higher injury rate in rugby has resulted in many injury prevention initiatives being implemented worldwide over the years.[9-14] Specifically, the BokSmart Rugby Safety Programme was formally introduced in South Africa in 2009 in an attempt to reduce injuries, with a main focus on catastrophic concussion, head, neck and spine injuries.[15] Previously, the BokSmart programme was linked to a decrease in the number of catastrophic injuries in junior players over time in South African rugby.[16] The programme was also associated with improvements in targeted injury prevention behaviours in players.[15]

In the absence of an accessible longitudinal youth rugby cohort, the South African Rugby (SA Rugby) Youth Week tournaments, which have been the source of multiple research studies in the past,[6, 17-21] is a practical and sustainable source of information on injuries in youth rugby in South Africa. These tournaments provide a convenient and reliable sample in which the effect of time on injury rates in South African youth rugby may be evaluated. The annual SA Rugby Youth Week tournaments began in 1964, and consist of the best 22 rugby players in each of the 14 provincial rugby unions across South Africa, per age-group division. The Youth Weeks consist of four week-long tournaments: the under-13 Craven Week (CWu13); the under-16 Grant Khomo (GKu16), and; two under-18 tournaments (Academy Week

[AWu18] and Craven Week [CWu18]).[17, 19] These tournaments include invitational teams from Namibia and Zimbabwe. This large number of high quality rugby players competing in a single competition provides a relatively homogenous sample per age group per year for injury surveillance and longitudinal comparison.

Therefore, the main aim of this study was to explore the changes in time-loss injury rates at the SA Rugby Youth Week tournaments between 2011 and 2016. Secondary aims were to determine whether there is any difference in overall time-loss injury incidence between the age-groups, and to investigate the associated injury risk factors.

Methods

Injury data collection was performed at four youth tournaments (CWu13, GKU16, AWu18 and CWu18) from 2011 to 2016, with each tournament varying in structure over the years (see Supplementary Table 2.1 for further details). A dedicated medical doctor was stationed at each tournament to assess any injury complaints experienced by players. The definition of an injury for the tournaments was slightly adapted from the rugby injury surveillance Consensus Statement[22] to “*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 and required attention from the SA Rugby tournament doctor*”. The details regarding every injury seen by the doctor were recorded on an injury collection form (Appendix II), by a designated tournament researcher at the time of injury, which was designed in accordance with the injury surveillance Consensus Statement and has been used in previous studies (all studies used the same methodology).[17, 19, 22]

The SA Rugby Medical and Anti-Doping informed consent forms were signed by both the player and their guardian/parent before the tournaments. The informed consent also included a section on injury surveillance and the usage of injury data for research purposes. Players were not allowed to participate in the tournament if this document was not signed. All data was depersonalized before it was received from SA Rugby, who own the data. Ethical clearance was granted by SA Rugby and the UCT Human Research Ethics Committee (HREC 438/2011) to access this injury database for research purposes.

“Time-loss” and “medical attention” injuries were recorded during the tournaments. “Time-loss” injuries were confirmed either at the tournament by the tournament doctor, or by telephonic follow-ups on a weekly basis after the tournament by the allocated tournament researcher. For this study, only time-loss injuries were analysed. The phase of play (tackler, ball-carrier, ruck, open play, running etc.), injury type (joint (non-bone)/ligament, central/peripheral nervous system, broken bone/fracture, muscle/tendon, bruise/contusion, laceration, other injury, unsure), game quarter (first, second, third or fourth) and injury location (both specific injury locations and grouped locations: head/neck, trunk, upper limb, lower limb) were analysed for longitudinal differences over the years and between the age-group tournaments (definitions as per the Consensus Statement were used).[22]

Statistical Analyses

Player exposure was calculated using the current Consensus Statement:[22]

$$Exposure = NM \times PM \times DM$$

For this equation, *NM* is the number of matches played, *PM* is the number of players per match, (always 30 players, number of players on the pitch at any given time), and *DM* is the duration of the match in hours. Exposure was used to determine the injury incidence per 1000 player match hours (injury incidence density) and the corresponding 95% Confidence Intervals (CI). Poisson regression analysis using IBM SPSS Statistics 24 (2016) was performed to determine if there was a significant change in injuries over time and if there were differences in injury incidences between years, between tournaments and between the various risk factors. For the factors affecting injury incidence, these were analysed as grouped variables over the four tournaments and six years because of the small numbers involved. A centred second order polynomial using GraphPad Prism version 5.0 for Windows, was used for trends over time for all injuries and injuries per tournament.

Results

Over six years (2011-2016) there were 795 matches including 7,470 players resulting in 24,240 exposure hours from the four tournaments and 494 time-loss injuries (Table 2.1).

Table 2.1: Breakdown of match exposure hours and Time-Loss injury incidence density (IID) for the six years of Youth Week tournament injury data.

Year	Matches	Injuries	Exposure	Time-Loss IID (95%CI)
2011	132	92	3945	23.3 (18.6-28.1)
2012	134	79	4000	19.8 (15.4-24.1)
2013	130	52	3860	13.5 (9.8-17.1)
2014	135	79	4215	18.7 (14.6-22.9)
2015	132	78	4110	19.0 (14.8-23.2)
2016	132	114	4110	27.7 (22.6-32.8)
Total	795	494	24 240	20.4 (18.6-22.2)

Combined and Tournament Time-Loss Injury Incidence

The time-loss injury incidence for all six years was 20.4 (18.6–22.2) injuries per 1000 player hours. Injury incidence density did not change significantly over time (Figure 2.1: $p=0.53$). When comparing grouped year data, only 2013 was significantly different (lower) compared to the 2011 base data. A decrease in IID was seen up until 2013, at which point the IID then began to increase (fitted polynomial line).

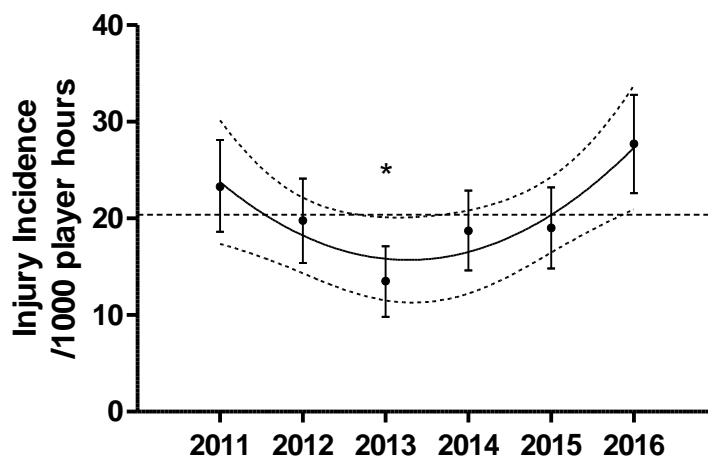


Figure 2.1: Injury incidence density, for time-loss injuries only, of the four SA Rugby Youth Week tournaments, between 2011 and 2016 (*significantly different to 2011; $P < 0.05$; horizontal dashed line represents average injury incidence over the six years; centred second order polynomial with dotted line representing 95% CI, $r^2=0.87$, $SEE=2.2$).

The average IIDs of the CWu13 (23.9 (19.5-28.2) injuries per 1000 player hours) and GK16 (22.2 (18.2-26.2) injuries per 1000 player hours) were significantly higher compared to the CWu18 (17.2 (14.0-20.5) injuries per 1000 player hours) base variable, demonstrating a decrease in incidence as age group increased (Figure 2.2). GK16 and AWu18 both followed a similar trend to that of the combined injury incidence, with a decrease until 2013 and then an increase again moving towards 2016, with CWu18 seeing a decrease in 2014 (Figure 2.2).

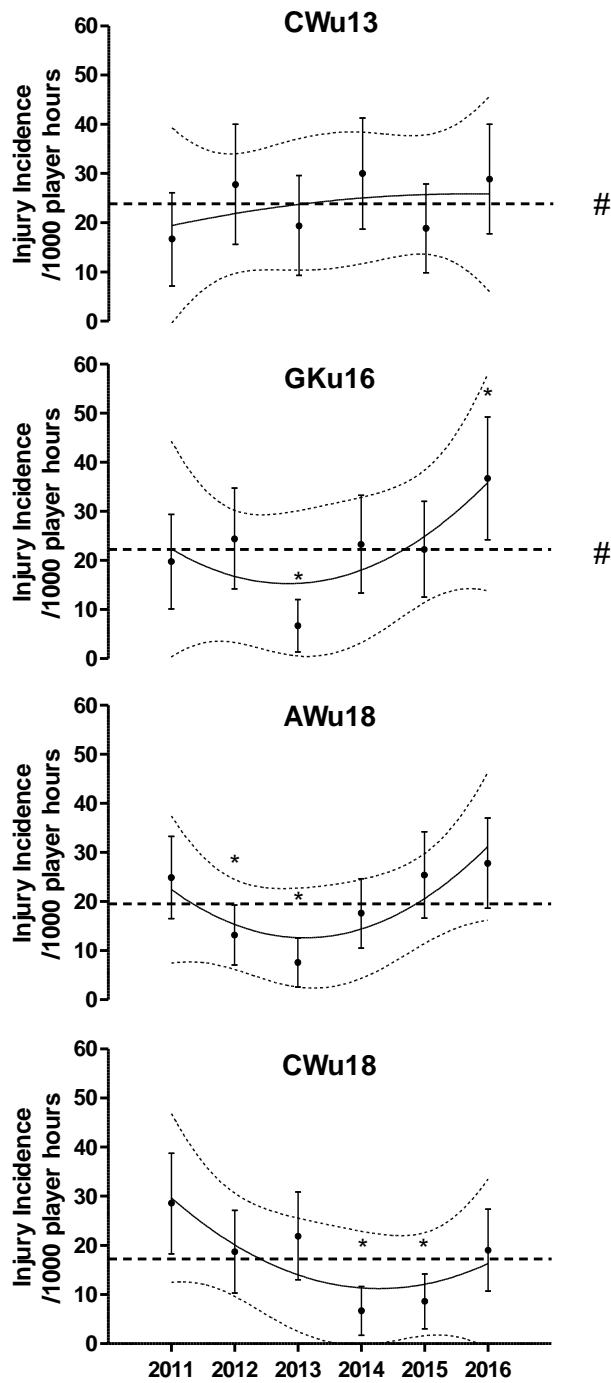


Figure 2.2: Individual SA Rugby Youth Week tournament injury incidence, for time-loss injuries only, between 2011 and 2016 (* significantly different to 2011; $p < 0.05$; # tournament average injury incidence significantly different to CWu18; dashed horizontal line represents average injury incidence over the six years for each tournament; centred second order polynomial with dotted line representing 95% CI, CWu13 $r^2=0.18$ SEE=6.9, GKu16 $r^2=0.62$ SEE=7.6, AWu18 $r^2=0.74$ SEE=5.2, CWu18 $r^2=0.69$ SEE=6.0).

Grouped Data

Even though there was a difference in the point estimates, the data could not be analysed with confidence because of the small numbers involved. Therefore, the factors affecting injury incidence were analysed as grouped variables over the four tournaments and six years.

Injury Event

Tacklers were injured at an incidence of 7.4(6.3–8.5) injuries per 1000 player hours which was significantly greater when compared to all other phases of play (Figure 2.3).

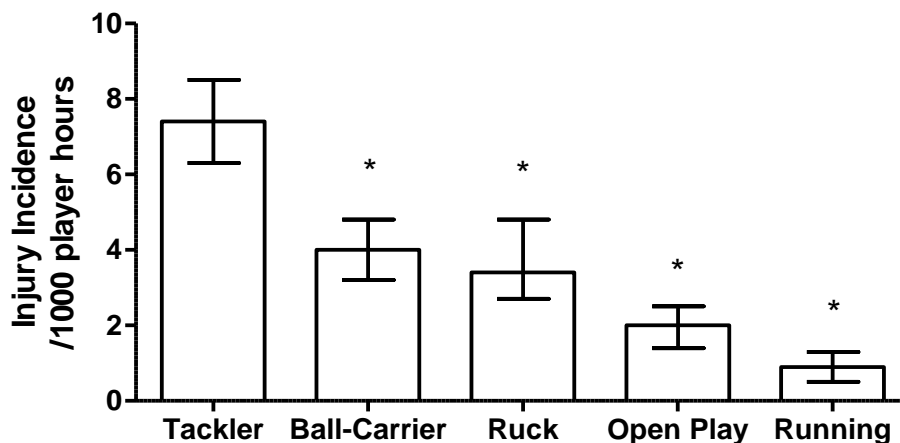


Figure 2.3: Injury incidence for the grouped SA Rugby Youth Week tournament 'phase of play' data, averaged over the period 2011 to 2016. (*significantly different to the Tackler; $p < 0.05$).

Injury Location

When looking at the specific locations, 34% of injuries over the six years were sustained to the head/face area, and 16% to the shoulder/collarbone (Table 2.2). The knee and ankle were the most commonly injured lower extremity sites, each with 12% of total injuries. When these specific injury locations were grouped into the four general injury locations (i.e. head/neck, upper limb, trunk, lower limb), the head/neck region was the most injured location over the six years with an injury incidence of 8.3 (7.1–9.4) injuries per 1000 player hours (Figure 2.4). The lower limb was the second most injured location with an incidence of 6.6 (5.6–7.6) injuries per 1000 player hours, but this incidence was still significantly lower than the head/neck region.

Table 2.2: Specific injury locations of all injuries over the period 2011 to 2016 (presented as a percentage of all injuries; n=494)

Injury Location	Injuries (%)
Head/Face	34
Shoulder/Collarbone	16
Knee	12
Ankle	12
Neck/Cervical	7
Wrist	2
Hand/Finger/Thumb	2
Hip/Groin	2
Back of Thigh	2
Lower Leg	2
Upper Arm	1
Elbow	1
Forearm	1
Sternum/Ribs	1
Low Back	1
Front of Thigh	1
Foot/Toe	1

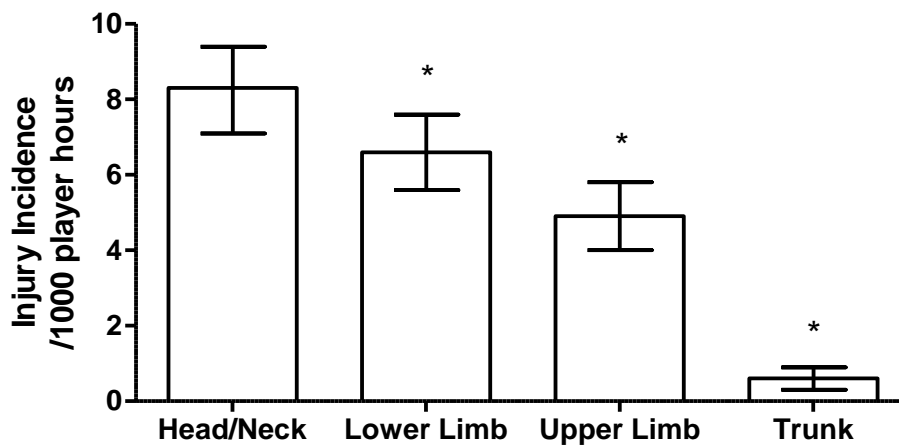


Figure 2.4: Injury incidence data per injury location for the grouped SA Rugby Youth Week tournaments averaged over the period 2011 to 2016 (* significantly different to Head/Neck as the base variable)

Injury Type

The central and peripheral nervous system (CNS/PNS) with an incidence of 6.3 (5.3–7.3) injuries per 1000 player hours and the joint (non-bone)/ligament category at 6.2 (5.2–7.2) injuries per 1000 player hours, were the most commonly occurring injury types across all years and tournaments (Figure 2.5). Concussions contributed to the majority of CNS/PNS injuries, and occurred during the tackle and ruck situations mostly. For concussions only, the incidence

was 5.9 (5.0–6.9) concussions per 1000 player hours. The trend in concussions decreased until 2013, and increased in 2014-2016, which followed a similar pattern to the overall injury rate trend over time (Figure 2.1). Ankle ligament injuries and shoulder/collarbone joint injuries made up the majority of the joint (non-bone)/ligament injuries. Most of the shoulder/collarbone injuries occurred during the tackle event, whilst the ankle injuries occurred during the tackle and open play situations.

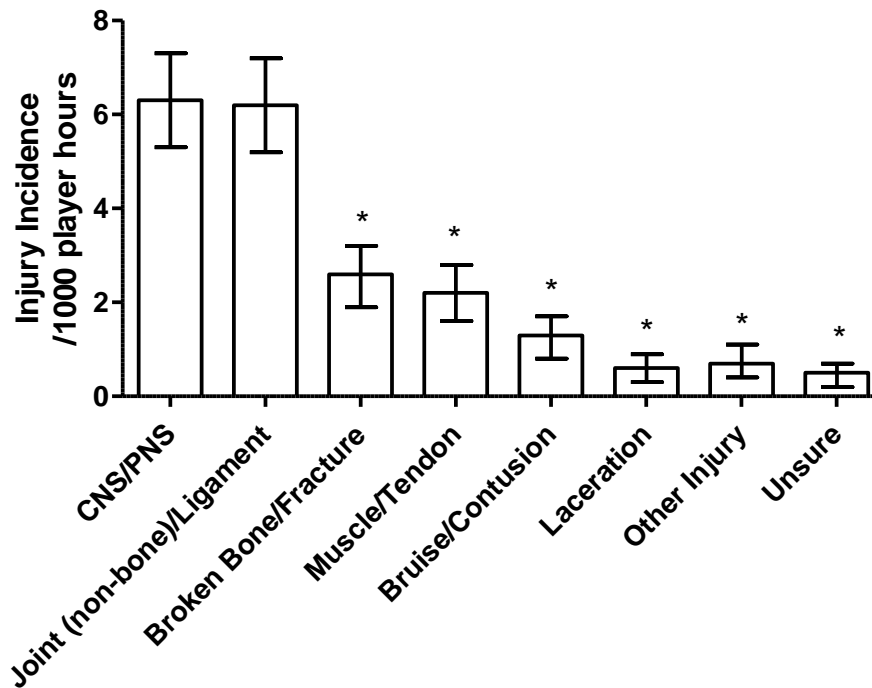


Figure 2.5: Injury incidence of the various injury types for the grouped SA Rugby Youth Week tournaments averaged over the period 2011 to 2016 (*significantly different to CNS/PNS - Central Nervous System/Peripheral Nervous System).

Match Period

The third quarter with 21.1(17.5–24.8) injuries per 1000 player hours and fourth quarter with 22.6(18.8–26.4) injuries per 1000 player hours had significantly higher injury incidences compared to the first quarter, at 15.7(12.5–18.8) injuries per 1000 player hours.

Discussion

The aims of the study were to determine if there was change in time-loss injury incidences over the six years of the study, and also to examine differences between the age groups and factors associated with injury incidences in youth rugby in South Africa. The overall injury rates remained stable, however there were significant differences between age groups and injury rates. There were also significant differences between the factors associated with injury.

Combined and Tournament Time-Loss Injury Incidence

The average injury incidence from 2011 to 2016 for the SA Rugby Youth Week tournaments was 20.4 (18.6–22.2) injuries per 1000 player hours. Injury incidence has remained relatively stable over the six years, except for 2013 where there was a significant decrease in injury rates. The year 2013 had the lowest number of injuries and lowest exposure hours. The overall incidence reported in this study is less than most other studies who have reported on time-loss injuries in youth cohorts. Palmer-Green *et al.* [5] reported an injury incidence of 35 injuries per 1000 player hours in school players. Studies by Hislop *et al.* [10] and Archbold *et al.* [23] had incidences of 30 injuries per 1000 player hours (control group), and 29 injuries per 1000 player hours, respectively. It must, however, be noted that all of the above studies were performed over a rugby season(s), whereas this study was performed over high-intensity week-long tournaments, with the country's best players in each respective age group, playing approximately three matches during each week. However, as these tournaments feature selected players of a high-calibre, there might be less of a mismatch in skill and size compared to that of a regular school playing in a typical rugby season in South Africa.

When the injury data are broken down into the age groups, our findings show that the injury rate decreased with increasing age (averaged over the six years), which is contradictory to Haseler *et al.* (2010) who showed that the U18 age category had significantly higher injury rates to that of the U13 age group, with players followed over a single season.[8] It must be noted that the Haseler study was performed over a season, whereas our study was over a week-long tournament, which could account for some of this difference. The combined tournament and injury incidence data showed a trend, which saw an initial drop in rates until 2013, and then an upward shift in injury incidence from 2014 to 2016. This pattern was largely due to the individual GKU16 and AWU18 tournaments. This change from 2013, can partly be attributed to the similar trend in the concussion injury incidence, which had the same turning point in 2013. In the second cycle of national BokSmart training (beginning late in 2011)[13] emphasis

was placed on concussion identification, its treatment and management, which led to tighter and stricter protocols applied at the SA Rugby tournaments. This increase in concussions, and therefore in total injuries reported, might simply be a reflection of this increased awareness, identification and reporting of suspected and confirmed concussions.

This increase in injury incidence could also be an effect of players at the tournaments continually increasing in mass and stature.[24] However, there is currently no evidence to support this assumption. The trend towards an increase in incidence needs to be monitored and the format of the tournaments should be restructured if necessary, based on the injury data presented at the time.

Injury Event

It is well documented that the tackle event in rugby is the phase of play with the highest associated injury risk.[3, 5, 8, 25-29] This was confirmed in our study, where the tackler had a significantly higher injury incidence compared to all other phases of play. Ball carried into contact was the phase of play with the next highest injury incidence. In other youth cohorts, the tackle event was analysed as a whole and not divided into separate tackler and ball-carrier roles, however, Palmer-Green found that the ball-carrier contributed to 32% of injuries compared to the tackler only contributing to 25%.[5, 8] The ruck was the next largest contributor to injuries in other youth cohorts; similar to our Youth Week cohort where the ruck had the highest injury incidence after the tackler and ball-carrier.[5, 8] Injury rates in the tackle have been shown to decrease with better technique, illustrating that coaching is an effective intervention,[20] in contrast to exercise interventions in collision sports.[30] However, it must be noted that a recent exercise intervention did show a reduction in concussion rates in youth rugby players.[10] This previous ineffectiveness in exercise interventions could be due to fewer injuries occurring in open play/running, and most injuries being contact related. Therefore, regardless of age group or level of play, the tackle event, including both tackler and ball-carrier roles, has the highest injury risk of all phases of play and needs continued attention in education and injury prevention programmes.[10-13, 31]

Injury Type and Location

In this study, the central and peripheral nervous system (CNS/PNS) was the most commonly recorded injury type, with joint (non-bone)/ligament injuries having a slightly lower injury incidence (but not significant). Similarly, in youth cohorts, Palmer-Green *et al.* showed that joint (non-bone)/ligament injuries occurred more often than muscle/tendon injuries, but

CNS/PNS injuries were one of the lowest reported injury types (this was before raised concussion awareness).[5] The rise in concussion rates have been seen in previous studies in the English Premiership[32] and the Australian sporting population,[33] where increased awareness has been acknowledged as factor. This injury profile is different to the professional game, where muscle/tendon injuries are the most common.[3] However, in the professional game, even though joint (non-bone)/ligament injuries are still prominent, the CNS/PNS injury rates are lower than both joint (non-bone)/ligament and muscle/tendon injuries.[3]

The overall incidence of concussions in this study was 5.9 injuries per 1000 player hours, which is in contrast to Haseler *et al.* who reported an incidence of only 1.8 injuries per 1000 player hours over a season.[8] However, in a more recent cluster-randomized controlled trial, the control group had similar rates to the SA Rugby Youth Week tournaments, with an incidence of 8 injuries per 1000 player hours for concussions over a season.[10] This difference between Haseler *et al.* and the recent data could be due to the rise in awareness and recognition, the more conservative inclusion of both suspected and confirmed concussions, and the presence of a dedicated medical doctor at every tournament.[17, 34] The large number of suspected and confirmed concussions is a concern, especially as this is within the youth population. The trend for concussions to increase from 2014, should be monitored over time to determine if this is a consequence of increased awareness and better reporting or a real effect. The current increasing pattern also provides an opportunity for the development of preventative measures, such as a recent study of English schoolboy players which showed reductions in concussions in youth.[10] Furthermore, another study has also shown the potential for contact technique effecting concussion risk.[21]

CNS/PNS injuries were the most common recorded injury type (mostly consisting of concussions), which was also reflected in the head/neck location being the most injured body location. This rate was significantly higher than injuries to the lower and upper limbs. In previous research at senior professional rugby, the lower limb is usually the most commonly injured body part, and in youth rugby data the lower limb and upper limbs are usually injured more frequently than the head/neck.[3, 5, 8, 25] Hislop *et al.* showed, in both control and intervention groups, similar findings to the SA Rugby Youth Week tournaments, with the head/neck being the most commonly injured body location.[10]

The injury types and body location profiles at the SA Rugby Youth Week tournaments are different to some of the older studies performed in both youth cohorts and professional rugby, but are similar to more recent studies performed in youth rugby, even over season long interventions.

Match Period

The third and fourth quarters in this study had significantly higher injury incidence rates compared to the first quarter of matches played, indicating an increased injury risk as match time progressed. In professional rugby a similar pattern was evident, however, even the second quarter was shown to have an increased risk compared to the first quarter.[3, 25] This could be an effect of fatigue, as tackle technique has been shown to worsen with increasing levels of fatigue.[3] The third quarter is often an increased risk period in a match due to the preceding half-time break, and players not warming-up sufficiently before the second-half kicks off, and/or a lack of concentration following the break.[35] The possible effects of player substitutions, and changes in on-field playing combinations might also require further exploration. These results of increasing injury incidence per match quarter supports the current literature and indicates that regardless of the age of the players involved, injury risk increases, as the match time progresses. Coaches need to consider this when making substitutions and formulating strength and conditioning plans. Also, SA Rugby and the tournament medical staff need to be sufficiently prepared for an influx of injuries towards the end of matches by having sufficient medical personnel and supplies.

A limitation of the study was the lack of severity data for the recorded injuries. Understanding the severity of the injuries provides further insight into the burden of rugby injuries in the South African youth population.

Perspective

The SA Rugby Youth Week tournaments provide a unique cohort of youth rugby players participating in high intensity week-long tournaments every year and cover different age groups. The injury data collected over the six years (2011-2016) has a lower time-loss injury incidence compared to the older studies on youth cohorts over a rugby season(s), but in line with more recent studies. There has been a trend towards an increase in injuries over the six years, and this increase in incidence is largely due to an increase in CNS/PNS injuries. This finding might solely be due to a prominent focus shift on concussions, more sensitive criteria in place for its identification, treatment and management, more education and greater awareness on the topic. To explore this concept further, these findings and conclusions should be compared to new tournament data from future studies. Within the SA Rugby tournament structure, as the players increase with age, the injury rates decreased, with the tackle event still being the phase of play with the highest injury incidence regardless of age. In these

tournaments, the role of tackler, as opposed to the ball-carrier, leads to significantly more injuries. These findings will assist SA Rugby to enhance their injury prevention programmes and help tailor them to the various age groups and injury concerns prevalent within the South African context.

References

1. Meir R, Halliday A. Pre- and post-game body mass changes during an international rugby tournament: a practical perspective. *J Strength Cond Res.* 2005;19:713-16.
2. World Rugby. Year in Review 2016. 2016 [cited 2018 June 17]. <http://www.worldrugby.org/documents/annual-reports?lang=en>.
3. Williams S, Trewartha G, Kemp S, Stokes K. A meta-analysis of injuries in senior men's professional Rugby Union. *Sports Med.* 2013;43(10):1043-55.
4. Fuller CW, Raftery M, Readhead C, Targett SG, Molloy MG. Match injuries in Southern Hemisphere professional rugby union: Impact of the International Rugby Board's Experimental Law Variations. *S Afr Med J.* 2009;99(4):232.
5. Palmer-Green DS, Stokes KA, Fuller CW, England M, Kemp SPT, Trewartha G. Match injuries in English youth academy and schools Rugby Union: an epidemiological study. *Am J Sports Med.* 2013;41(4):749-55.
6. Mc Fie S, Brown J, Hendricks S, et al. Incidence and Factors Associated With Concussion Injuries at the 2011 to 2014 South African Rugby Union Youth Week Tournaments. *Clin J Sport Med.* 2016;26(5):398-404.
7. Hootman JM, Dick R, Agel J. Epidemiology of Collegiate Injuries for 15 Sports: Summary and Recommendations for Injury Prevention Initiatives. *J Athl Train.* 2007;42(2):311-19.
8. Haseler CM, Carmont MR, England M. The epidemiology of injuries in English youth community rugby union. *Br J Sports Med.* 2010;44(15):1093-99.
9. Hendricks S, Lambert MI, Brown JC, Readhead C, Viljoen W. An evidence-driven approach to scrum law modifications in amateur rugby played in South Africa. *Br J Sports Med.* 2014;48(14):1115-19.
10. Hislop MD, Stokes KA, Williams S, et al. Reducing musculoskeletal injury and concussion risk in schoolboy rugby players with a pre-activity movement control exercise programme: a cluster randomised controlled trial. *Br J Sports Med.* 2017;51:1140-46.
11. Australian Rugby Union. Key points for the tackler and ball-carrier, Australian Rugby Union SmartRugby: Confidence in contact. A guide to the SmartRugby Program.2008:18-19.
12. New Zealand Rugby Union. Technique: the key factors in the tackle and taking the ball into contact. RugbySmart 2007: A guide to injury prevention for peak performance.2007:12-14.
13. Viljoen W, Patricios J. BokSmart – implementing a National Rugby Safety Programme. *Br J Sports Med.* 2012;46(10):692-93.
14. Sewry N, Verhagen E, Lambert M, van Mechelen W, Brown J. Evaluation of the Effectiveness and Implementation of the BokSmart Safe Six Injury Prevention Programme: a study protocol. *Inj Prev.* 2017;23:428.
15. Brown JC, Gardner-Lubbe S, Lambert MI, Van Mechelen W, Verhagen E. The BokSmart intervention programme is associated with improvements in injury prevention behaviours of rugby union players: an ecological cross-sectional study. *Inj Prev.* 2015;21(3):173-78.
16. Brown JC, Verhagen E, Knol D, Van Mechelen W, Lambert MI. The effectiveness of the nationwide BokSmart rugby injury prevention program on catastrophic injury rates. *Scand J Med Sci Sports.* 2016;26(2):221-25.
17. Brown J, Verhagen E, Viljoen W, et al. The incidence and severity of injuries at the 2011 South African Rugby Union (SARU) Youth Week tournaments. *S Afr J Sports Med.* 2012;24:49-54.

18. Brown JC, Viljoen W, Lambert MI, et al. The economic burden of time-loss injuries to youth players participating in week-long rugby union tournaments. *J Sci Med Sport*. 2015;18(4):394-99.
19. Burger N, Lambert MI, Viljoen W, Brown JC, Readhead C, Hendricks S. Tackle-related injury rates and nature of injuries in South African Youth Week tournament rugby union players (under-13 to under-18): an observational cohort study. *BMJ Open*. 2014;4(8).
20. Burger N, Lambert MI, Viljoen W, Brown JC, Readhead C, Hendricks S. Tackle technique and tackle-related injuries in high-level South African Rugby Union under-18 players: real-match video analysis. *Br J Sports Med*. 2016;50(15):932-38.
21. Hendricks S, O'connor S, Lambert M, et al. Contact technique and concussions in the South African under-18 Coca-Cola Craven Week Rugby tournament. *Eur J Sport Sci*. 2015;15(6):557-64.
22. Fuller C, Molloy M, Bagate C, et al. Concensus statement on injury definitions and data collection procedures for studies of injuries in rugby union. *Br J Sports Med*. 2007;41:328-31.
23. Archbold HAP, Rankin AT, Webb M, et al. RISUS study: Rugby Injury Surveillance in Ulster Schools. *Br J Sports Med*. 2017;51(7):600-06.
24. Durandt J, Green M, Masimla H, Lambert M. Changes in body mass, stature and BMI in South African elite U18 Rugby players from different racial groups from 2002–2012. *J Sports Sci*. 2017:1-8.
25. Brooks J, Fuller C, Kemp S, Reddin D. Epidemiology of injuries in English professional rugby union: part 1 match injuries. *Br J Sports Med*. 2005;39:757-66.
26. Brooks J, Fuller C, Kemp S, Reddin D. Epidemiology of injuries in English professional rugby union: part 2 training injuries. *Br J Sports Med*. 2005;36:767-75.
27. Fuller C, Molloy M. Epidemiological study of injuries in men's international under-20 rugby union tournaments. *Clin J Sports Med*. 2011;21:356-58.
28. Nathan M, Goedeke R, Noakes T. The incidence and nature of rugby injuries experienced at one school during the 1982 rugby season. *practice*. *S Afr Med J*. 1983;18(18):15.
29. Roux CE, Goedeke R, Visser, G.R., van Zyl, W.A., amp, Noakes TD. The epidemiology of schoolboy rugby injuries. *S Afr Med J*. 1987;71(5):307-313.
30. Sewry N, Verhagen E, Lambert M, et al. Exercise-based interventions for injury prevention in tackle collision ball sports: a systematic review. *Sports Med*. 2017:1-11.
31. Patricios J. BokSmart - South African rugby's national rugby safety and injury prevention program. *Curr Sports Med Rep*. 2014;13(3):142-44.
32. Cross M, Trewartha G, Kemp S, et al. Concussion in rugby union: improved reporting, a more conservative approach or an increased risk? *Br J Sports Med*. 2017;51(4):309.
33. Finch C, Clapperton A, J. , McCrory P. Increasing incidence of hospitalisation for sport-related concussion in Victoria, Australia. *Med J Aus*. 2013;198(8):427-30.
34. Raftery M. Concussion and chronic traumatic encephalopathy: International Rugby Board's response. *Br J Sports Med*. 2014;48(2):79-80.
35. Bathgate A, Best J, Craig G, Jamieson M. A prospective study of injuries to elite Australian rugby union players. *Br J Sports Med*. 2002;36:265-69.

Supplementary Table 2.1: Tournament format over the years. (M = Match day where some teams play, TM = Tournament Match day where every team at the tournament plays, R = Rest day where no team plays)

Year	Craven Week U13			Grant Khomo U16			Academy Week U18					Craven Week U18		
	2011-2013	2014-2015	2016	2011	2012-2015	2016	2011 - 2012	2013	2014	2015	2016	2011	2012	2013 – 2016
Teams (n)	18	18	18	26	24	20	26	26	26	24	24	20	20	20
Matches (n)	36	36	36	39	36	30	39	34	39	36	36	30	29	30
Duration (min)	40	50	50	70	70	60	70	70	70	70	70	70	70	70
Structure	M,M,R,M,M		M,M,R,M	M,M,R,M		M,R,M, R,M	M,M,R,M				TM,TM,TM, TM,R,TM	TM,TM,TM,TM,R,TM		
Exposure (hours)	720	900	900	810	900	900	1365	1190	1365	1260	1260	1050	1015	1050

CHAPTER 3:

EXERCISE-BASED INTERVENTIONS FOR INJURY PREVENTION IN TACKLE COLLISION BALL SPORTS: A SYSTEMATIC REVIEW

Published as:

Sewry, Verhagen, Lambert, van Mechelen, Viljoen, Readhead, Brown. Exercise-Based Interventions for Injury Prevention in Tackle Collision Ball Sports: A Systematic Review. *Sports Medicine*, 2017;47(9): 1847-1857

Abstract

Background

The injury burden in collision sports is relatively high compared to other team sports. Therefore, participants in these sports would benefit by having effective injury prevention programs. Exercise-based interventions have successfully reduced injuries in soccer, but evidence on exercise-based interventions in tackle collision sports is limited. The aim of the study was to systematically examine the evidence of exercise-based intervention programs reducing injuries in tackle collision sports.

Methods

Data sources: PubMed, EBSCOHost and Web of Science were searched for articles published between January 1995 and December 2015. The methodological quality was assessed using an adapted Cochrane Bone Joint and Muscle Trauma Group quality assessment tool.

Study selection: The inclusion criteria were: 1) (randomized) control trials and observational studies 2) sporting codes: American, Australian and Gaelic Football, rugby union and rugby league 3) participants of any age or sex 4) exercise-based, prehabilitative intervention, and 5) primary outcome: injury rate or incidence (injury risk). The exclusion criteria were: 1) unavailability of full-text, 2) article unavailable in English.

Results

Nine studies with a total of 3517 participants were included in this review. Seven of these studies showed a significant decrease in injury risk. These studies included three sporting codes and various age groups, making it difficult to make inferences. The two highest methodological quality studies found no effect of an exercise-based intervention on injury risk.

Conclusions

There is evidence that exercise-based injury preventions can be beneficial in reducing injury risk in collision sports, but more studies of high methodological quality are required.

Introduction

Collision sports, including Australian Football, American Football and Rugby union (henceforth referred to as ‘rugby’) are popular sports played across the globe. These sports are characterized by intermittent, high intensity bouts of exercise interspersed with heavy bodily collisions (such as tackles).[1-3] This contact is of a ballistic nature, with high force- and momentum-generating movements, and thus collision sports are associated with a relatively high injury burden.[4-10] The injury incidence in tackle collision sports is higher than that of other non-collision sports (such as soccer).[11, 10] In collision sports, injuries can have a large economic cost, as well as a negative effect on team performance, which demonstrates the urgent need for effective injury prevention strategies.[12, 13]

Sports injury risk reduction interventions have adopted a wide variety of intervention modalities, including exercise-based programs. Effective exercise-based programs are dependent on good compliance.[14, 15] Another critical component to the program’s effectiveness is the exercise intervention itself. In soccer players, Nordic hamstring strengthening exercises were associated with a decrease in hamstring injury incidence.[16] In soccer and basketball, the FIFA 11+ exercise program is an effective whole-body injury reduction intervention.[17-19] However, rugby has different physical characteristics to both soccer and basketball, such as tackling and bodily collisions, and therefore it is not known whether these results can be translated to rugby.

Accordingly, the aim of this review was to systematically examine the evidence for the effectiveness of exercise-based intervention programs in reducing injury risk in collision sports that incorporate tackling in the game.

Methods

Search Methods

The databases PubMed, EBSCOHost and Web of Science were searched for relevant articles that were published between January 1995 and December 2015. The following combination of keywords was used when searching: ((rugby union) or (rugby league) or (rugby) or (AFL) or (NFL) or (Football) or (Gaelic Football)) AND (injury or injuries) AND ((exercise) or (warm-up) or (resistance training) or (proprioception) or (rehabilitation) or (prehabilitation) or (train*) or (balance) or (strength*) or (neuromuscular)). The results of these searches were then

combined and the duplicate articles removed. Additionally, the reference list of included studies and relevant systematic reviews were searched for further relevant studies.

Eligibility Criteria

The citations were initially screened using the title and abstract. Articles were independently screened and selected by two authors (NS, JB) if they fitted the following criteria:

Inclusion

- Controlled trials (i.e. cluster-randomized controlled trial, randomized controlled trials or quasi-randomized controlled trials), observational studies (i.e. prospective cohort, retrospective cohort, time-series studies)
- Sporting code was: rugby union, rugby league, Australian Football, American Football or Gaelic Football players (any age, level of play or sex)
- Primary outcome was injury rate or injury incidence, further referred to as ‘injury risk’.
- The intervention was prehabilitative and exercise-based

Exclusion

- Full-text for the article was unavailable
- The article was not available in English

The full-text articles were independently assessed for eligibility using the inclusion and exclusion criteria by two authors (NS, JB). Any disagreements on article eligibility were resolved through discussions between the two reviewers, without the need for the involvement of a third author.

Data Collection

The following information was extracted from the included articles by the two authors (NS, JB) and is presented in Table 1: authors, year of publication, study design, participants’ details (type of sport, age, sex, level of competition, number of participants), definition of the primary outcome, details of the intervention and the effect of the intervention (including a level of statistical significance).

Assessment of Methodological Strength of Included Studies

Both reviewers (NS, JB) scored the selected articles independently according to a modified version of the Cochrane Bone Joint and Muscle Trauma Group quality assessment tool

(eliminated was measure “G = were care programs, other than the trial options, clearly identical?”)[20] to assess the methodological strength, with any disagreements resolved through discussion. Each item on the check-list was given a grade from 0 – 2 (0 = not possible to rate/not defined/not mentioned, 1 = inadequate description/application or not adjusted for, 2 = clearly defined or effective action in the case of blinding), with a maximum possible composite score of 22 representing the methodological strength. Median scores of studies that did and did not show an effect of the intervention were compared using a Wilcoxon ranked sum test using Stata (StataCorp 2011: Release 12, Collect Station, TX: StataCorp, LP). The study design for each article was also determined using the Oxford Centre for Evidence Based-Medicine – Levels of Evidence.[21]

Results

Study Selection

Electronic (3216) and manual (37) searches for articles resulted in a total of 3253 articles. After duplicate articles were removed, the remaining 2150 articles were screened, using the title and abstract; 2125 articles were excluded for reasons including incorrect sporting code or study design (no articles were excluded on the basis of no full-text available). For the remaining 25 full-text articles a further 16 articles were excluded, due to eligibility criteria without disagreement between NS and JB (Figure 3.1).

Study Characteristics

Following the study selection process (Figure 3.1), nine studies with a total of 3517 participants were included in this review. These nine studies included six observational studies and three controlled trials. The number of participants in the observational studies ranged from 27 to 546 players and the controlled trials ranged from 220 to 1564 participants. These participants were all male, and consisted of both youth and senior players of amateur (five studies) and professional status (four studies). The sporting codes of the selected studies included American and Australian Football and rugby union. The follow-up periods for the observational studies were between two seasons (two years) and four seasons (four years),[22-27] whereas the controlled trials were all one season (26, 22 or 12 weeks).[28-30]

Methodological strength

The methodological strength of the nine studies had a range of scores from 7 to 21 (the lower the score, the worse the methodological quality of the study) (Figure 3.2). Only three of the studies fulfilled more than 50% of the criteria: these three studies were the controlled trials.[28-30] The observational studies had the lowest methodological quality scores, as they did not

blind subjects, assessors or therapists.[22-25, 27] The methodological strength was reduced because baseline comparability between experimental and control groups was lacking and frequently not adjusted for in most of the studies, regardless of study design.[22, 23, 28, 24, 25, 27] Only three of the studies were of a high methodological strength (score ≥ 16). These three studies were all performed in Australian Football; all three were controlled trials.[28-30] Two of these three studies did not find a decrease in injury risk.[28, 29] However the third study, which assessed a motor control intervention, found a decrease in injury risk.[30] The six lower methodological quality studies all found a decrease in injury risk and were spread across American Football, Australian Football and rugby.[22-27] It is important to note the methodological quality of each study, as this affected the inferences made throughout the Results and Discussion sections.

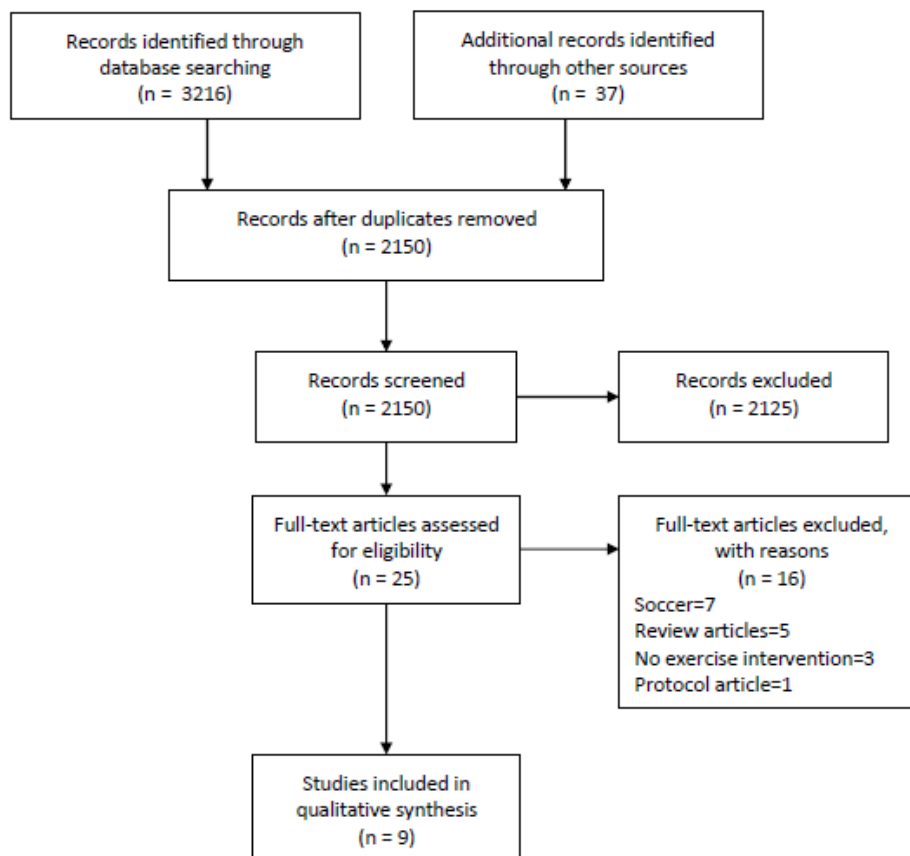


Figure 3.1: Flow diagram of the search strategy and study selection.

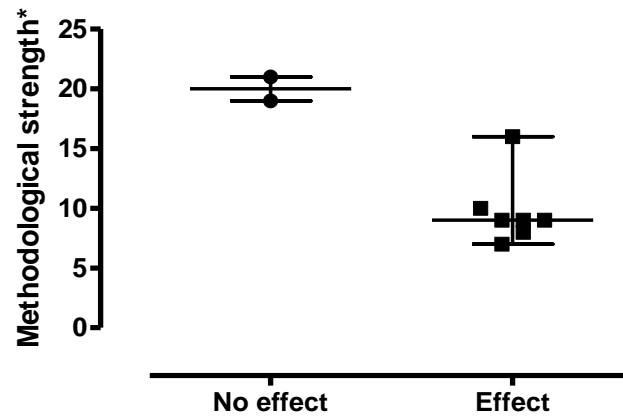


Figure 3.2: Difference between reported intervention effects on injury rates and the methodological strength of the study reporting the effect. On average, those studies reporting an intervention effect on injury rates had a significantly lower methodological strength rating than those studies that showed no effect ($p=0.037$). Circles represent studies with no significant change, squares represent studies with a significant positive result. Median and range values are depicted. ¹Methodological strength was determined using a modified version of the Cochrane Bone Joint and Muscle Trauma Group quality assessment tool.[20]

Table 3.1: Characteristics of each included study.

Study	Composite score (methodological strength) ^a	Study design ^b	Follow-up period	Male participants (n) ^c	Primary outcome	Intervention	Effect of intervention
Gabbe et al., 2006 [29]	21	Controlled trial	1 season, 12 weeks	Australian Football players from the Victorian Amateur Football Association (n = 220) <u>Control</u> group: n = 106; age 23.9 (17.4-36.0) years <u>Intervention</u> group: n = 114; age 23.4 (18.0-35.0) years	Hamstring injury; training and match; only time-loss	<u>Control</u> : stretching, range of motion including gastrocnemius, hip flexors, hamstrings (supine and sitting), lumbar spine rotation (3 x 30s) <u>Intervention</u> : eccentric hamstring exercises (6 repetitions, 12 sets). 5 session program, first 3 sessions in pre-season (each 2 weeks apart), 4 th and 5 th session were in-season (3 weeks apart).	No effect (unknown if match or training or both) RR= 1.2 (95% CI 0.5 – 2.8)
Finch et al., 2015 [28]	19	Controlled trial	1 season, 26 weeks	Non-elite, community-level Australian Football players (n = 1564), age unknown	Injury incidence; match injuries; only time-loss	<u>Control</u> group: sham exercise program, similar to regular training (twice a week) <u>Intervention</u> : neuromuscular and biomechanical exercises focusing on lower limb injury prevention (twice a week)	No effect IRR= 0.92 (95% CI 0.68 – 1.23)
Hides and Stanton, 2014 [30]	16	Controlled trial	1 season, 22 weeks	Elite, national Australian Football club players (n = 46) age 22.8±3.5 years	Injury incidence; training and match; only time-loss	<u>Group 1</u> : motor control training (7 wk), advanced motor control training (8 wk), Pilates (7 wk) <u>Group 2</u> : Pilates (7 wk), motor control training (8 wk), Pilates (7 wk) <u>Group 3</u> : Pilates (7 wk), Pilates (8 wk), motor control training (7 wk)	Motor control training occurring before time point 3 significantly decreased the occurrence of an injury (match and training) p=0.017
McHugh and Mullaney, 2007 [24]	10	Observational	3 seasons, 3 years	University American Football teams (n = 125), age 15-18 years	Ankle sprain injury number; training and match injuries; only time-loss	<u>Control</u> (Previous player seasons, pre-intervention): status quo <u>Intervention</u> (3 seasons): single-limb balance training on foam stability pad (5min each leg, pre-season: 5 days/week for 4 weeks; in-season: 2x/week for 9 weeks)	Significantly decreased incidence of ankle injuries (match and training) p<0.01
Naish et al., 2013 [25]	9	Observational	2 seasons, 2 years	Professional Super 14 rugby union players (n = 27) age 25.2±3.9 years	Cervical spine injury number and severity; training and match; only time-loss	<u>Control</u> (1 st season): status quo <u>Intervention</u> (2 nd season): 13-week isometric neck strengthening program, 13-week maintenance phase	Significant decrease in the number of injuries in matches p=0.03 No effect on severity of injuries p=0.40
Scase et al., 2006 [26]	9	Observational	2 seasons, 2 years	Under 18 Australian Football players from the national competition (n = 723) <u>Control</u> group: n = 609; age 17.0±2.6 years <u>Intervention</u> group: n = 114; age 17.0±2.5 years	Injury incidence and severity; training and match; only time-loss	<u>Control</u> : status quo <u>Intervention</u> : 6 landing, falling and recovery skills taught, initially on a mat, progressed to game situations (8x30 minute sessions) during pre-season	Significantly reduced injury incidence (match and training) IRR 0.72 (95% CI 0.52-0.98) No effect on severity of injury (match and training) p=0.39

Verrall et al., 2005 [27]	9	Observational	4 seasons, 4 years	Male professional Australian Football players (n =70)	Hamstring injury incidence; training and match; only time-loss	<u>Control (1st& 2nd season)</u> : status quo <u>Intervention (3rd & 4th season)</u> : increased high intensity anaerobic interval running drills, hamstring stretches, specific football drill, lower limb weight training.	Significant decrease in match hamstring injury incidence IRR 0.27 (95% CI 0.08-0.76)
Cross and Worrell, 1999 [23]	8	Observational	2 seasons, 2 years	Division III college American Football players (n =195); age 18.6±1.5 years	Lower extremity musculotendinous strains incidence; training and match; only time-loss	<u>Control (1st season)</u> : status quo <u>Intervention (2nd season)</u> : stretching program incorporated (hamstrings, quadriceps, hip adductors, gastrocnemius)	Significant decrease in incidence of lower extremity muscle injuries (match and training) p<0.05
Brooks et al., 2006 [22]	7	Observational	2 seasons, 2 years	English Premiership rugby union clubs (546) <u>Strengthening group</u> : n = 148; age 25.5±4.1 years <u>Stretching group</u> : n = 144; age 25.8±4.0 years <u>Nordic strengthening</u> : n = 200; age 25.4±4.1 years	Hamstring injury incidence and severity; training and match; only time-loss	<u>Strengthening group</u> : regular concentric and eccentric hamstring exercises <u>Stretching group</u> : static stretching at least once a week, and regular concentric and eccentric hamstring exercises <u>Nordic strengthening group</u> : same as the above two, and includes Nordic hamstring exercises	No difference in match injury burden. Significant decrease in all injuries incidence in the stretching (IRR =0.59 (95% CI 0.34-0.84)) and Nordic strengthening group (IRR=0.39 (95% CI 0.25-0.54)) (compared to the strengthening group IIR=1.1 (95% CI 0.74-1.40))

^a Based on a modified version of the Cochrane Bone Joint and Muscle Group study quality assessment tool.[20]

^b Using the Oxford Centre of Evidence-Based Medicine categorization.[21]

^c Age data are mean (range or ± SD)

RR = relative risk

IRR = injury rate ratio

IIR = injury incidence rate

CI = confidence interval

SD = standard deviation

Bold text indicates that the intervention was associated with a significant reduction in injury risk

Injury Definitions

The definition for an injury was similar throughout most studies, and included a statement similar to that of the rugby injury consensus statement by Fuller *et al.* (2007) for a time-loss injury defined as “an absence from training or match participation for more than 24 hours after the injury”.[31] However, the studies included in this review used variations of this definition, with the difference between a time-loss and medical attention injury (“an injury resulting in less than 24 hours absence from training or match participation”) being unclear in most of them.[31] The primary outcome was sometimes specific to a body location of specific interest to the intervention, for example hamstring injuries only.[22, 29, 27] Depending on the study, the injury outcome was measured either by injury risk and/or severity of injury (number of days missed due to injury). Some studies recorded only match injuries. However, if a study reported both match and training injuries separately, these results were presented separately (Table 3.1).[22, 30]

Exercise Intervention Type

In the observational studies, balance training, Nordic drops and plyometric training were associated with significant decreases in injury risk. Two of the studies in this review included eccentric hamstring exercises as the primary intervention. In the studies that examined this intervention in rugby union and Australian Football, one found no decrease in match injury risk,[28] and the other found a decrease in training injury risk.[21] The other common exercise intervention used by three of the studies, was that of neuromuscular and proprioceptive training. The controlled trials used neuromuscular and biomechanical exercises as the intervention, but after adjusting for confounders there was no significant change in injury risk.[28] However, in a cohort of junior American Football players, foam pad balance training resulted in a significant decrease in the injury risk of ankle sprains.[24] The majority (n = 6) of the nine interventions used a single modal exercise – five of these six interventions were associated with an injury reduction.[22, 23, 29, 30, 24, 25] Of the three remaining multimodal interventions, two were associated with injury reductions.[28, 26, 27]

Intervention Effectiveness

Seven of the nine studies were associated with a significant decrease in injury risk and therefore were effective in injury risk reduction. Of these seven studies, four grouped training and match injuries together,[23, 30, 24, 26] two used only match injuries and showed a decrease in injury risk (Naish *et al.* $p=0.03$:[25] Verrall *et al.* relative risk (RR) 0.267, 95% CI 0.076 to 0.764)[27]

and one separated match and training injuries and showed a decrease in training injury risk (p-value or RR not mentioned).[22] However, the two studies that were not associated with a decrease in injury risk had significantly higher median methodological quality (p=0.037, Finch *et al.*,[28] and Gabbe *et al.*).[29] Despite having the highest methodological quality, these two studies were difficult to compare due to differences in injury definitions. Specifically, the definitions of Finch *et al.* [28] were aligned with those of the rugby consensus statement (without directly referring to it).[31] In contrast, the study of Gabbe *et al.* [29] was published before the rugby consensus statement and their injury definition did not require a player to be absent from training or match participation.[31] Scase *et al.* (2006) found that their falling, landing and recovery skills-based exercise intervention was associated with a significant increase in time to sustaining a landing injury compared to the control group who continued as per usual (RR 0.40, 95% CI 0.17 to 0.92).[26] In this original paper, the authors incorrectly stated “the time to sustaining a landing injury was significantly less for the intervention group”. However, their graphical representation clearly indicates that the time to injury increased, not decreased. Although three of the nine studies assessed the effect of an exercise modality on severity of injury, none found an effect on this outcome.[22, 25, 26]

Injury Type

Three of the nine studies focused on interventions to reduce hamstring injury risk. One of these three hamstring studies found no intervention effect.[29] However, the two hamstring studies that were associated with a decrease in injury risk were observational studies that also had the lowest level of evidence, and methodological quality.[22, 27] One of the hamstring studies that had an effect was an observational study where the teams were grouped according to their usual training regime: (i) strengthening exercises, (ii) static stretching and (iii) a group that included both (i) and (ii) components and further added Nordic hamstring exercises.[22] The second observational study, which also found a decrease in hamstring injury risk, implemented a two-year intervention, after two seasons of prior baseline measurement, with the intervention consisting of high intensity anaerobic interval running drills, hamstring stretches, weight training and football drills.[27] The hamstring study that was not associated with a change in injury risk was a controlled trial where the intervention group implemented eccentric hamstring exercises and the control group performed lower body stretching and range of motion exercises.[29] The six other studies focused on a wider range of injuries, using and including a range of different exercise modalities. These modalities included motor control training,[30] neuromuscular and biomechanical training,[28] and landing, falling and recovery skills,

specifically for game situations.[26] For example, a stretching program was used as an intervention for lower extremity injuries,[23] a single limb balance training intervention was implemented for ankle sprains,[24] and a progressive isometric neck strengthening program was used to reduce cervical neck injuries.[25]

Sporting Code

The nine studies were performed in three sports: Australian Football (n=5), American Football (n=2) and rugby union (n=2). The two American Football studies were associated with significant reductions in injury risk, one specifically in ankle injuries and the other in lower extremity injury risk.[23, 24] Both these studies were observational studies and their definitions of an injury included both match and training injuries together. However, the age groups of the two study samples were distinctly different; one was college athletes and the other group below eighteen years.[23, 24] Of the five Australian Football studies, three were associated with a significant decrease in injury risk. The variation in study designs and age of participants of the five Australian Football studies made them difficult to compare.[28-30, 26, 27] The last two studies were observational studies conducted in rugby union; the one in professional and the other in amateur clubs with participants over the age of eighteen.[22, 25]

Compliance

Compliance is another important aspect of the effectiveness of an intervention program. Four studies report compliance as a factor.[22, 23, 27, 28] Two of these studies measured compliance in some way; Finch *et al.* [27] reported compliance in terms of numbers of sessions attended but merely stated that most players did not attend both sessions every week (determined to be ineffective in injury prevention), while Gabbe *et al.*[28] reported the percentage of players attending at least two of the five sessions (an effective injury prevention program). The two American Football studies simply reported that compliance was “good” as the coaches and athletic trainers ensured attendance.[22, 23] Another possible reason for the “good” compliance in these two studies might have been that the intervention was easily incorporated into regular training as it was a simple stretching program prior to practice and balance training, performed at weight training sessions.

Discussion

This review systematically evaluated the effectiveness of various exercise-based interventions on injury risk in sports involving tackle collisions such as Australian Football, American Football and rugby union. Seven of the nine reviewed interventions were effective in reducing

injury risk, with one of these having a high methodological quality. The two studies which showed no change in injury risk were both of high methodological quality, illustrating conflicting evidence. This outcome suggests that more research is necessary to evaluate the potential to prevent injury in collision sports through exercise-based interventions.

Whilst the sporting codes included in this review all have similar physical demands in terms of their collision nature, their rules differ fundamentally and therefore affect the injury etiology. This feature of multiple sporting codes in this review, makes it difficult to compare to previous reviews performed in single sports such as soccer. There are multiple reviews looking at soccer injury prevention programs. In one review, half of the studies had a statistically significant outcome, with six out of the seven studies having at least a moderate methodological quality.[32] This moderate methodological quality can be attributed to the fact that four of the studies included in the said review were randomized controlled trials. A second review of intervention effectiveness in soccer only included the FIFA 11+ exercises and showed a 30-70% reduction in injuries across the included studies. This review consisted of five randomized controlled trials, six observational studies showing the effectiveness of a warm-up integrated injury prevention program in soccer.[33] The difference between the soccer reviews and the present review is the nature of the sports. The sports included in this review include a constant aspect of collisions/tackles, which is absent from soccer. To identify and develop an injury prevention program for such sporting codes is far more complex, than for a sport where the main contact focus is on the lower limbs. This dynamic and unpredictable nature of collision sports could be a contributing factor to the inconclusive data obtained in the present review.[2]

The type of exercise intervention implemented is important to an effective program. For example American Football players had a significant decrease in the injury incidence of ankle sprains following foam pad balance training.[24] This is consistent with previous literature in soccer players and basketball players, where balance training (using wobble boards, single leg balance and functional activities performed on one leg) was associated with a decrease in ankle injury risk.[34, 35] Eccentric hamstring curls (also known as Nordic drops) were included in two of the studies in this review. They have also been shown to be effective in various age groups in multiple studies in soccer and basketball players, and are a widely accepted preventative exercise.[16, 36, 37] However, in the studies that examined this intervention in rugby union and Australian Football, one found no decrease in match injury risk,[28] and the other (in rugby union) found a decrease in training injury risk.[21] A review performed by Rössler *et al.* (2014) showed that interventions that included balance, jumping and plyometric

exercises provided better results than those that did not, and this would support the present review's results.[38] This indicates that even with the collision nature of the sports, these aspects of training are important to incorporate into a prevention program. Furthermore Rössler *et al.* (2014) concluded that injury-specific programs, as opposed to “global” prevention programs, tended to deliver better results.[38] In our review there was only one true “global” program (Finch *et al.*),[27] and we therefore could not compare global programs to single programs and determine which had better results.[28] However, it must be noted that the comparison between injury-specific and “global” programs is problematic as certain injuries often deemed non-preventable are not included in the data analysis of injury-specific programs.

Although compliance is an important factor for intervention effectiveness,[39] only two of the nine studies included in our review reported on this effect. The “Preventing Australian Football injuries” intervention had low compliance and no effect on injury risk. Most participants did not attend both sessions every week, and their intervention consisted of multiple components, requiring considerable time.[28] Whilst the study design was of a high quality, its complex nature could have made it too demanding for the participants and therefore difficult to adhere to. It must be noted that Finch *et al.* (2015) [28] used an ITT (intention-to-treat) analysis to account for compliance. However, this method has recently come under scrutiny and it is worth considering PP (per protocol) analysis to determine the effects of the intervention as per the protocol performed by the participant.[15] As a result, it was not possible to conclude whether the lack of intervention effectiveness in the Finch *et al.* (2015) study was a result of poor compliance or not.[28]

However, another program in Australian Football, with a relatively simple intervention consisting of eccentric hamstring curls, had a 50% drop in attendance from the first to second session. Only 49% of players completed at least two of the sessions.[29] Thus, despite this intervention's simplicity and time-efficiency this study also reported poor compliance and no effect on injury risk.[29] The compliance in the motor control training program in Australian Football is unknown. The intervention consisted of predominantly individual sessions, which could have been a contributing factor to the program being more effective in injury risk reduction.[30] Similarly, both Scase *et al.* [26] and Verrall *et al.* [27] (also Australian Football) made no mention of the compliance with their programs, but both had positive reductions in injury risk. This is important to note, as one of the programs was integrated into the preseason team training, and therefore, did not require extra time from the participants.[27] Compliance in the Brooks *et al.* [22] rugby union study was not measured and groups were only stratified

conveniently according to their habitual training regimes. Nonetheless, these authors found a significant reduction in training-related hamstring injuries in the “intervention” group. However, as the “intervention” was merely what the team already did at training, it is difficult to make any confident inferences from this study.[22] Compliance with the neck strengthening program in rugby union players was also unclear.[25] This study also had a complicated and time-consuming program, yet had positive injury risk reductions.[25] When analyzing the data on program effectiveness, adherence/compliance must be accounted for in the analysis to provide better context to the results and to better describe the program’s ‘real world’ application.

Although this review has comparisons to previous exercise-based intervention reviews performed in other sporting codes, the results are different and must be interpreted within the contexts that they have been implemented.

Limitations

The aim of the review was to systematically examine the evidence available on exercise-based interventions and their effectiveness in preventing injuries in sports with collision characteristics similar to rugby union. Whilst the review achieved its aim, there are limitations with the results presented in the review. The main limitation is that there is very limited research in this field for these types of sports. Only nine studies were included in this review. These studies span two decades of research and included multiple study design types. This indicates that the area is under-researched and lacks evidence for effective prevention strategies, despite the high injury risk that is present in these collision sports.

Additionally, the studies did not address all types of injuries. In particular there was a lack of evidence for upper body injuries. This needs to be addressed because the shoulder is one of the most commonly injured sites in tackle collision sports.[10] The review also included studies conducted on a variety of age groups – it is unknown if the intervention effectiveness would be affected by the age of the participant. Another potential limiting factor in this review is the heterogeneity of sporting codes included. Although we only included sports where collisions and tackles occur, the demands of the sporting codes are not completely comparable and thus caution must be exercised when extrapolating these findings to other sports.[39] The lack of methodological strength of six of the nine studies is an important limitation of this review. This methodological strength was calculated using a quality assessment tool. However, a limitation of any methodological assessment tool is that it can only assess what its authors report on.

Hypothetically, a study design can actually be worse or better than the score derived from the information provided by the authors. Additionally, certain study designs could be scored poorly, but be appropriate in a certain setting. An example of this in our review is the studies in an elite/professional setting that used teams as their own controls over subsequent seasons.[22, 25, 27] It would be very difficult to have a true control for an elite team. Neither of these identified drawbacks are unique to our assessment tool or easy to correct, but should be considered when interpreting study strength. Furthermore, with regards to the observational studies, two did perform the interventions for longer periods of time, and this greater exposure to the intervention could have contributed to the positive results. However, it is unknown if the same players participated in the intervention in both seasons and therefore received a greater exposure.

Conclusion

Based on the high-quality studies (n=3, out of 9) in this review, there are currently minimal effective exercise-based injury prevention programs for tackle collision sports. The interventions in the low methodological strength studies that reduced injury risk also warrant further investigation. These studies with low methodological quality listed simple and easy to implement interventions, and were conducted over prolonged periods (2 – 4 seasons). They all incorporated hamstring exercises, balance training and stretching components. However, the lack of consistency, generally low methodological quality and low number of studies available limits the conclusions that can be drawn. There is a need for further high-quality research and more randomized controlled trials to be performed in interventions designed to reduce the injury risk in tackle collision sports. The results of these studies should also be reported in accordance with available injury surveillance consensus statements for comparability. The studies also need to record and report compliance with the intervention to obtain a measure of exposure or ‘dose’ of the intervention, and relate changes in injury data to this exposure. That said, this review does add new information, as these collision sports have yet to be grouped and viewed as a unit. Furthermore, this review provides components to consider for research into, and design of, injury prevention programs for tackle collision sports.

References

1. Duthie G, Pyne D, Hooper S. Applied physiology and game analysis of rugby union. *Sports Med.* 2003;33(13):973-91.
2. Hendricks S, Lambert M. Tackling in rugby: coaching strategies for effective technique and injury prevention. *Int J Sports Sci Coach.* 2010;5(1):117-31
3. Quarrie K, Hopkins W. Tackle injuries in professional rugby union. *Am J Sports Med.* 2008;36(9): 1705-16.
4. Hendricks S, Karpul D, Lambert M. Momentum and kinetic energy during the tackle in rugby union. *J Sports Sci Med.* 2014;13(3):557-63.
5. Hendricks S, Lambert MI, Brown JC, et al. An evidence-driven approach to scrum law modifications in amateur rugby played in South Africa. *Br J Sports Med.* 2014;48(14):1115-9.
6. Quarrie K, Wilson B. Force production in the rugby union scrum. *J Sports Sci.* 2000;18:237-46.
7. Burger N, Lambert MI, Viljoen W, et al. Tackle-related injury rates and nature of injuries in South African Youth Week tournament rugby union players (under-13 to under-18): an observational cohort study. *BMJ Open.* 2014;4(8).
8. Ekegren CL, Gabbe BJ, Donaldson A, et al. Injuries in community-level Australian football: Results from a club-based injury surveillance system. *J Sci Med Sport.* 2015;18(6):651-5.
9. Hootman JM, Dick R, Agel J. Epidemiology of collegiate injuries for 15 sports: Summary and recommendations for injury prevention initiatives. *J Athl Train.* 2007;42(2):311-9.
10. Williams S, Trewartha G, Kemp S, et al. A meta-analysis of injuries in senior men's professional Rugby Union. *Sports Med.* 2013;43(10):1043-55.
11. Bengtsson H, Ekstrand J, Waldén M, et al. Match injury rates in professional soccer vary with match result, match venue, and type of competition. *Am J Sports Med.* 2013;41(7):1505-10.
12. Verhagen EALM, van Mechelen W. Sport for all, injury prevention for all. *Br J Sports Med.* 2010;44(3):158.
13. Brown JC, Viljoen W, Lambert MI, et al. The economic burden of time-loss injuries to youth players participating in week-long rugby union tournaments. *J Sci Med Sport.* 2015;18(4):394-9.
14. Verhagen E, Finch CF. Setting our minds to implementation. *Br J Sports Med.* 2011;45(13):1015-6.
15. Verhagen EALM, Hupperets MDW, Finch CF, van Mechelen W. The impact of adherence on sports injury prevention effect estimates in randomised controlled trials: Looking beyond the CONSORT statement. *J Sci Med Sport.* 2011;14(4):287-92.
16. van der Horst N, Smits D-W, Petersen J, et al. The preventive effect of the Nordic hamstring exercise on hamstring injuries in amateur soccer players: a randomized controlled trial. *Am J Sports Med.* 2015;43(6):1316-23.
17. Longo UG, Loppini M, Berton A, et al. The FIFA 11+ program is effective in preventing injuries in elite male basketball players: a cluster randomized controlled trial. *Am J Sports Med.* 2012;40(5):996-1005.
18. Owøye OBA, Akinbo SRA, Tella BA, et al. Efficacy of the FIFA 11+ warm-up programme in male youth football: a cluster randomised controlled trial. *J Sports Sci Med.* 2014;13(2):321-8.
19. Silvers-Granelli H, Mandelbaum B, Adeniji O, et al. Efficacy of the FIFA 11+ injury prevention program in the collegiate male soccer player. *Am J Sports Med.* 2015;43(11):2628-37.

20. Cochrane Bone Joint and Muscle Trauma Group. Quality Assessment Tool. 2006. <http://bjmt.cochrane.org/sites/bjmt.cochrane.org/files/public/uploads/Quality%20assessment%20tool.pdf>. Accessed 04 April 2016.
21. Phillips B, Ball C, Sackett D, et al. Oxford centre for evidence-based medicine levels of evidence. 2001. http://www.cebm.net/levels_of_evidence.asp. Accessed 10 April 2016.
22. Brooks JH, Fuller CW, Kemp SP, et al. Incidence, risk, and prevention of hamstring muscle injuries in professional rugby union. *Am J Sports Med.* 2006;34(8):1297-306.
23. Cross KM, Worrell TW. Effects of a static stretching program on the incidence of lower extremity musculotendinous strains. *J Athl Train.* 1999;34(1):11-4.
24. McHugh MP, Tyler TF, Mirabella MR, et al. The effectiveness of a balance training intervention in reducing the incidence of noncontact ankle sprains in high school football players. *Am J Sports Med.* 2007;35(8):1289-94.
25. Naish R, Burnett A, Burrows S, et al. Can a specific neck strengthening program decrease cervical spine injuries in a men's professional Rugby union team? A retrospective analysis. *J Sports Sci Med.* 2013;12(3):542-50.
26. Scase E, Cook J, Makdissi M, et al. Teaching landing skills in elite junior Australian football: evaluation of an injury prevention strategy. *Br J Sports Med.* 2006;40(10):834-8
27. Verrall GM, Slavotinek JP, Barnes PG. The effect of sports specific training on reducing the incidence of hamstring injuries in professional Australian Rules football players. *Br J Sports Med.* 2005;39(6):363-8.
28. Finch CF, Twomey DM, Fortington LV, et al. Preventing Australian football injuries with a targeted neuromuscular control exercise programme: comparative injury rates from a training intervention delivered in a clustered randomised controlled trial. *Inj Prev.* 2015. Sep 23: injuryprev-2015.
29. Gabbe BJ, Branson R, Bennell KL. A pilot randomised controlled trial of eccentric exercise to prevent hamstring injuries in community-level Australian Football. *J Sci Med Sport.* 2006;9(1-2):103-9.
30. Hides JA, Stanton WR. Can motor control training lower the risk of injury for professional football players? *Med Sci Sports Exerc.* 2014;46(4):762-8.
31. Fuller C, Molloy M, Bagate C, et al. Consensus statement on injury definitions and data collection procedures for studies of injuries in rugby union. *Br J Sports Med.* 2007;41(5):328-31.
32. van Beijsterveldt AMC, van der Horst N, van de Port IGL, et al. How effective are exercise-based injury prevention programmes for soccer players? *Sports Med.* 2013;43(4):257-65.
33. Barengo NC, Meneses-Echávez JF, Ramírez-Vélez R, et al. The impact of the FIFA 11+ training program on injury prevention in football players: a systematic review. *Int J Environ Res Public Health.* 2014;11(11):11986-2000.
34. McGuine TA, Keene JS. The effect of a balance training program on the risk of ankle sprains in high school athletes. *Am J Sports Med.* 2006;34(7):1103-11.
35. Verhagen E, Van der Beek A, Twisk J, et al. The effect of a proprioceptive balance board training program for the prevention of ankle sprains a prospective controlled trial. *Am J Sports Med.* 2004;32(6):1385-93.
36. Olsen O-E, Myklebust G, Engebretsen L, et al. Exercises to prevent lower limb injuries in youth sports: cluster randomised controlled trial. *BMJ.* 2005;330(7489):449.
37. Petersen J, Thorborg K, Nielsen MB, et al. Preventive effect of eccentric training on acute hamstring injuries in men's soccer a cluster-randomized controlled trial. *Am J Sports Med.* 2011;39(11):2296-303.
38. Rössler R, Donath L, Verhagen E, et al. Exercise-based injury prevention in child and adolescent sport: a systematic review and meta-analysis. *Sports Med.* 2014;44(12):1733-48.

39. Finch CF, Donaldson A. A sports setting matrix for understanding the implementation context for community sport. *Br J Sports Med.* 2010;44(13):973-8.

CHAPTER 4:

PLAYERS' AND COACHES' KNOWLEDGE AND AWARENESS OF THE BOKSMART *SAFE SIX* INJURY PREVENTION PROGRAMME: AN ECOLOGICAL CROSS-SECTIONAL QUESTIONNAIRE STUDY

Published as:

Sewry, Verhagen, Lambert, van Mechelen, Brown. Players' and coaches' knowledge and awareness of the BokSmart Safe Six injury prevention programme: an ecological cross-sectional questionnaire study. *BMJ Open*, 2017;7:e018575

Abstract

Background

Rugby has a high injury incidence and therefore BokSmart introduced the *Safe Six* injury prevention programme in 2014 in an attempt to decrease this incidence. In 2015, BokSmart used a “targeted marketing approach” to increase the awareness and knowledge of the *Safe Six*. Therefore, the aim of this study was to determine the change in the knowledge of coaches and players of the *Safe Six* programme, compared to the launch year, following a “targeted marketing approach”.

Methods

Using an ecological cross-sectional study design, questionnaires were completed by 4,502 players and coaches who attended any of the four South African rugby union youth week tournaments during 2014 – 2016. Logistic regression (adjusted odds ratio, 95% CI) was performed in comparison to year prior to targeted marketing, separately for coaches and players, for changes in awareness and knowledge.

Results

The awareness of the *Safe Six* increased significantly for players in 2015 (1.74 times [1.49; 2.04]) and in 2016 (1.54 times [1.29; 1.84]). Similarly, for coaches, there was a 3.55 times [1.23; 9.99] increase in 2015 and a 10.11 times [2.43; 42.08] increase in 2016 compared to 2014. Furthermore, a player was significantly more likely to be aware of the *Safe Six* if his coach was aware of the programme ($p < 0.05$).

Conclusions

The knowledge and awareness of the BokSmart *Safe Six* increased in 2015 and 2016 (compared to 2014). Coaches, the Unions/SARU and social media were the largest contributors to knowledge in coaches and players. Whilst the “targeted marketing approach” was associated with an increase in awareness, future studies should determine if this translates into behavioural change.

Introduction

Rugby union (hence referred to as “rugby”) is a sport played globally and has a high risk of injury when compared to other sports.[1-3] Owing to this high risk, multiple nationwide injury prevention programmes have been designed and implemented in various countries, such as RugbySmart in New Zealand and Smart Rugby in Australia.[4, 5] In South Africa, the South African Rugby Union (SARU) developed and implemented BokSmart in an attempt to decrease the injury burden through research-based initiatives.[6]

The BokSmart injury prevention programme focuses its initiatives through mandatory biennial courses, which are DVD-facilitated workshops for all coaches and referees in South Africa.[7] RugbySmart also targets the coaches and referees, and has been associated with decreases in spinal cord injuries and overall injury rates in specifically targeted areas.[8, 9] There was also an increase in “safe” behaviours in the contact situations following the introduction of RugbySmart.[8] Similarly, the BokSmart programme has also been associated with improvements in injury prevention behaviours in players, which is hypothesised to lead to a decrease in injuries.[10, 11] Furthermore, BokSmart has been associated with a decrease in catastrophic injuries in junior rugby players in South Africa.[12] These studies all indicate that the coach-targeted approach for injury prevention in rugby is successful.[11] These studies were all quantitative and descriptive studies, which provide information regarding changes over time in injury rates, knowledge and awareness of the programme and allow for inferences to be made.

Following the success of the BokSmart programme, BokSmart further developed and implemented the *Safe Six* exercise-based injury prevention programme in the beginning of 2014 (<http://boksmart.sarugby.co.za/content/safe-six>). The BokSmart *Safe Six* programme is coach-targeted, and aimed at being implemented as a warm-up before training or competition.[13] The *Safe Six* was developed using clinical knowledge and research to address the most commonly occurring injuries in rugby union, and was designed to be implemented by rugby players of all ages. As with all BokSmart programmes, whilst the *Safe Six* is coach-targeted, it is expected that there will be knowledge transfer from the coaches to the players.

This study had three aims. Firstly, to determine whether there was a change in the knowledge of coaches and players of the *Safe Six* programme, compared to the launch year, following a targeted marketing approach. Secondly, to evaluate whether a coach-targeted intervention

approach is associated with player knowledge and awareness of the *Safe Six* programme. Finally, to explore the reasons why coaches and players use the *Safe Six* programme.

Methods

Participants

The players and coaches of all South African teams attending the SARU youth week tournaments in 2014, 2015 and 2016 were invited to complete a questionnaire (repeat participants were not measured, but it is assumed that a small proportion of players and coaches would have completed the questionnaire in multiple years). The youth week tournaments are an annual opportunity to showcase the talent of the best youth rugby players in South Africa's various provincial unions. The youth week tournaments included in this study were the Under 13 Craven Week, U16 Grant Khomo Week, Under 18 Academy Week, Under 18 Craven Week, Under 18 Learners with Special Education Needs (LSEN) Week and Under 17 Sevens Tournament. The players and coaches were asked to complete the questionnaire independently at any point during the tournament and to return it to the tournament medical officer. Hard copies of the questionnaire were distributed to the players and coaches and their hand written responses were transferred into Excel for data entry and then into SPSS for statistical analysis. Each coach, parent of a player under the age of 18 and player gave written consent prior to the tournament to be involved in the study and the study received ethical clearance from the Human Research Ethics Committee of the University of Cape Town (HREC 108/2017).

BokSmart Safe Six Targeted Marketing

In 2014 BokSmart launched the *Safe Six* programme, but did not perform any explicit marketing; this is deemed the “pre” marketing period for the current study. In 2015, before the youth week tournaments, a targeted marketing approach was taken, using emails (including the full *Safe Six* programme) to the respective youth week coaches; i.e. provincial unions and SARU both provided informative material to all coaches attending the youth weeks. The social media accounts of SA Rugby Youth Weeks (10 172 Facebook and 1 959 Twitter followers, 2017) and BokSmart (4 060 Facebook and 2 996 Twitter followers, 2017) were used as platforms to market the *Safe Six* programme, and so the 2015 year is the “during” marketing period. The social media marketing included copies of the Safe Six posters (details regarding the exercises, repetitions and images) and links to YouTube instructional videos. This targeted marketing took place during the ten weeks leading up to all the tournaments in 2015. In 2016, similarly to 2014, no specific marketing was made towards those attending the youth weeks and can be considered the “post” marketing period.

Questionnaire

The questionnaire was designed by BokSmart to determine the players' and coaches' knowledge, behaviour and awareness of the *Safe Six* injury prevention programme. The BokSmart *Safe Six* is targeted at the coach and therefore the questionnaire (Appendix III) assesses knowledge (of the BokSmart *Safe Six*) and its transfer to behaviour (reported usage of the BokSmart *Safe Six*) of the coaches, as well as the barriers and facilitators in this process. The questionnaire also assesses the fidelity of knowledge by requiring the participants to correctly name the exercises included in the BokSmart *Safe Six* programme. Following this, the BokSmart coach-targeted approach would assume that this knowledge of the programme would transfer from the coach to the player, and therefore, the questionnaire also assesses the knowledge and behaviour of the players regarding the BokSmart *Safe Six*.

Statistics

Descriptive statistics were performed on the tournaments, the participants, their roles and their responses. Logistic regression was performed to determine an adjusted odds ratio (aOR, with 95% CIs) (adjusting for team role and year) on various binary outcomes (yes or no). All analyses were performed using IBM SPSS Statistics 23 (2015). Statistical significance was accepted when the $p < 0.05$.

Results

Over the three years of data collection a total of 4,502 participants completed the questionnaire from six different tournaments in three consecutive years. Of the participants, 92% were players, and the rest were coaches or of unknown role (Table 4.1).

Table 4.1: The team roles of participants who completed the questionnaire ($n=4502$).

Team Role	2014	2015	2016	Total
Coach	27	52	33	112
Player	1351	1715	1070	4136
Unknown	136	80	38	254
Total	1514	1847	1141	4502

For players, the awareness of the *Safe Six* increased significantly in 2015 (1.74 times [1.49; 2.04], $p < 0.001$) and in 2016 (1.54 times [1.29; 1.84], $p < 0.001$) compared to 2014 (Table 4.2). Similarly, for coaches, there was a 3.55 times [1.23; 9.99] ($p < 0.02$) increase in 2015 and a 10.11 times [2.43; 42.08] ($p < 0.001$) increase in 2016 compared to 2014. However, the difference between 2015 and 2016 for both coaches and players was not significant.

Table 4.2: Responses to the question “Have you ever heard of the BokSmart Safe Six?” (n=4050, unknown role=245, blank=207).

Team Role	2014		2015		2016		Total	
	No	Yes	No	Yes	No	Yes	No	Yes
Coach n (%)	13 (52)	12 (48)	11 (23)	36 (77)**	3 (10)	28 (90)**	27 (26)	76 (74)
Player n (%)	946 (73)	341 (27)	1002 (62)	627 (38)*	663 (64)	368 (36)**	2611 (66)	1336 (34)
Total	959 (73)	353 (27)	1013 (60)	663 (40)	666 (63)	396 (37)	2638 (65)	1412 (35)

Furthermore, in 2015 players were 4.94 [2.78; 8.80] times more likely to be aware of the *Safe Six* if their respective coaches were aware of the programme (Table 4.3).

Table 4.3: The players’ responses related to what their respective coaches answered to the question “Have you ever heard of the BokSmart Safe Six?” during 2015 (number of coaches = 47).

Coaches' Response	Players' Response % (n)		
	No	Yes	Total
No	20 (123)	2 (11)	22 (134)
Yes	46 (278)	32 (190)	78 (468)
Total	66 (401)	34 (201)	100 (602)

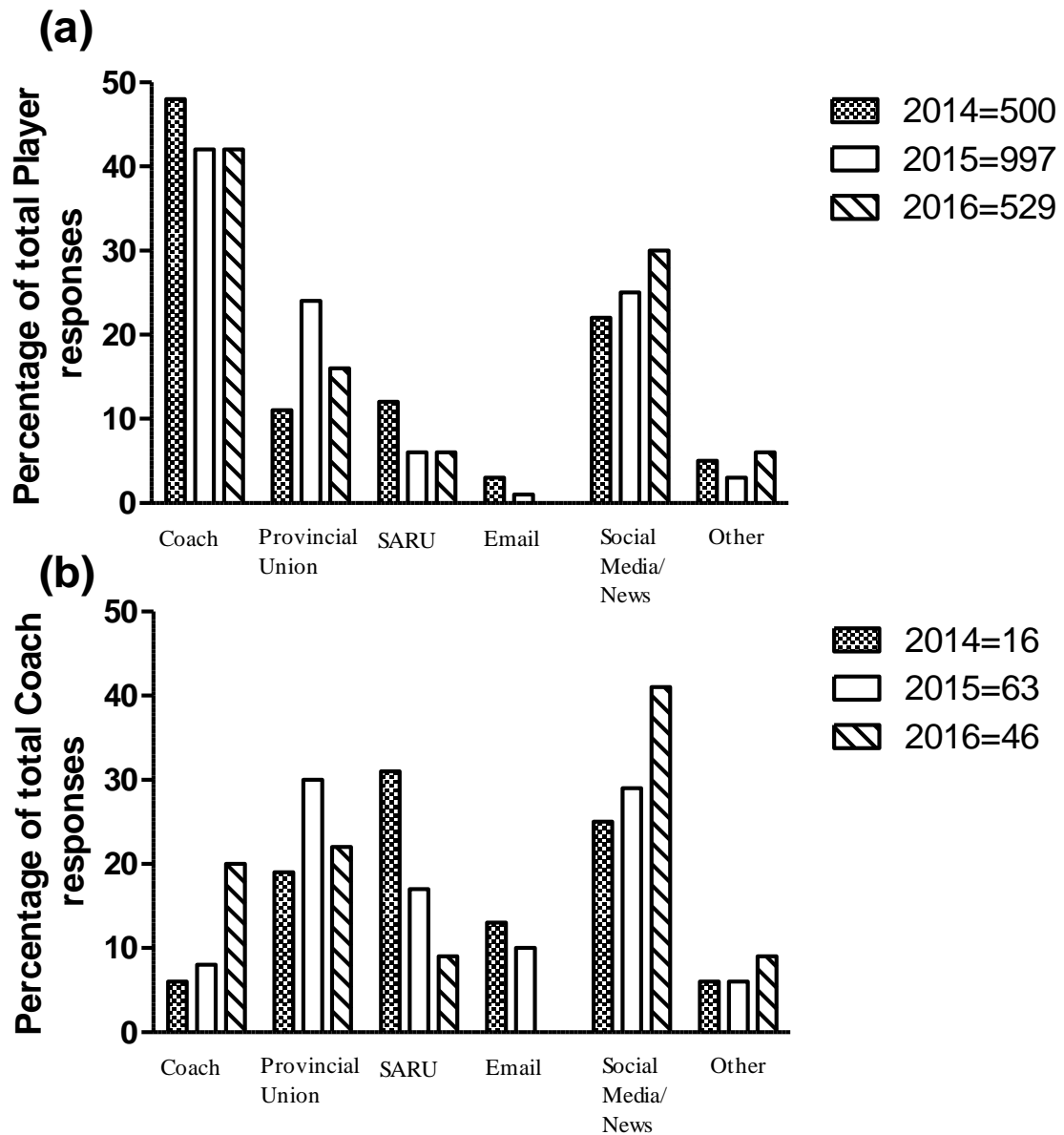


Figure 4.1a): Players' responses to the question "How did you come to hear about the BokSmart Safe Six?" (participants could choose multiple options). b) Coaches' responses to the question "How did you come to hear about the BokSmart Safe Six?" (participants could choose multiple options).

SARU (2014), provincial unions (2015) and social media/news (2016) were the largest sources of information of the *Safe Six* over the years for coaches (Figure 4.1). For players, the largest source of information regarding the *Safe Six* was through coaches, social media/news was the second largest and the provincial unions were also large contributors to the dissemination of knowledge.

The overall finding was that the players had a poor ability to name the exercises. Multiple participants could name some of the six exercises, but not all of them, and different combinations of the exercises (Table 4.4).

Table 4.4: The number of correct answers when the participants were asked to list as many of the BokSmart Safe Six exercises as they could remember in 2015 only.

Exercise	Coach	Players	Total
Six Meter Shuttle Run	22	321	343
Six Point Lunge	19	294	313
Buttsmart Six	14	257	271
Six-on-a-Side Push Up	16	247	263
Six Bok Lunge	18	223	241
Six Dynamic Reaches	17	139	156

In 2015 the reported usage of the *Safe Six* exercises was significantly higher for players than that of 2014 (aOR = 1.75 [1.36; 2.26], p<0.001), but in 2016 there was no significant change compared to 2014 (Table 4.5). For coaches, the usage was significantly higher in 2015, with a 4.14 times [1.15; 14.92] (p<0.03) increase, however in 2016 there was no significant change when compared to 2014. If a participant had answered “no” to “have they ever heard of the BokSmart Safe Six” they were screened to not be included in this question, however if they left that question blank, they could be included.

Table 4.5: Participants’ responses to the question “In the last 6-8 weeks have you ever used the BokSmart Safe Six exercises?” (n=1,599, blank=48).

Team Role	2014		2015		2016		Total	
	No	Yes	No	Yes	No	Yes	No	Yes
Coach n (%)	8 (50)	8 (50)	7 (19)	29 (81)**	6 (21)	22 (79)	21 (26)	59 (74)
Player n (%)	146 (43)	195 (57)	224 (32)	466 (68)*	233 (53)	207 (47)	603 (41)	868 (59)
Total n (%)	154 (43)	203 (57)	231 (32)	495 (68)	239 (51)	229 (49)	624 (40)	927 (60)

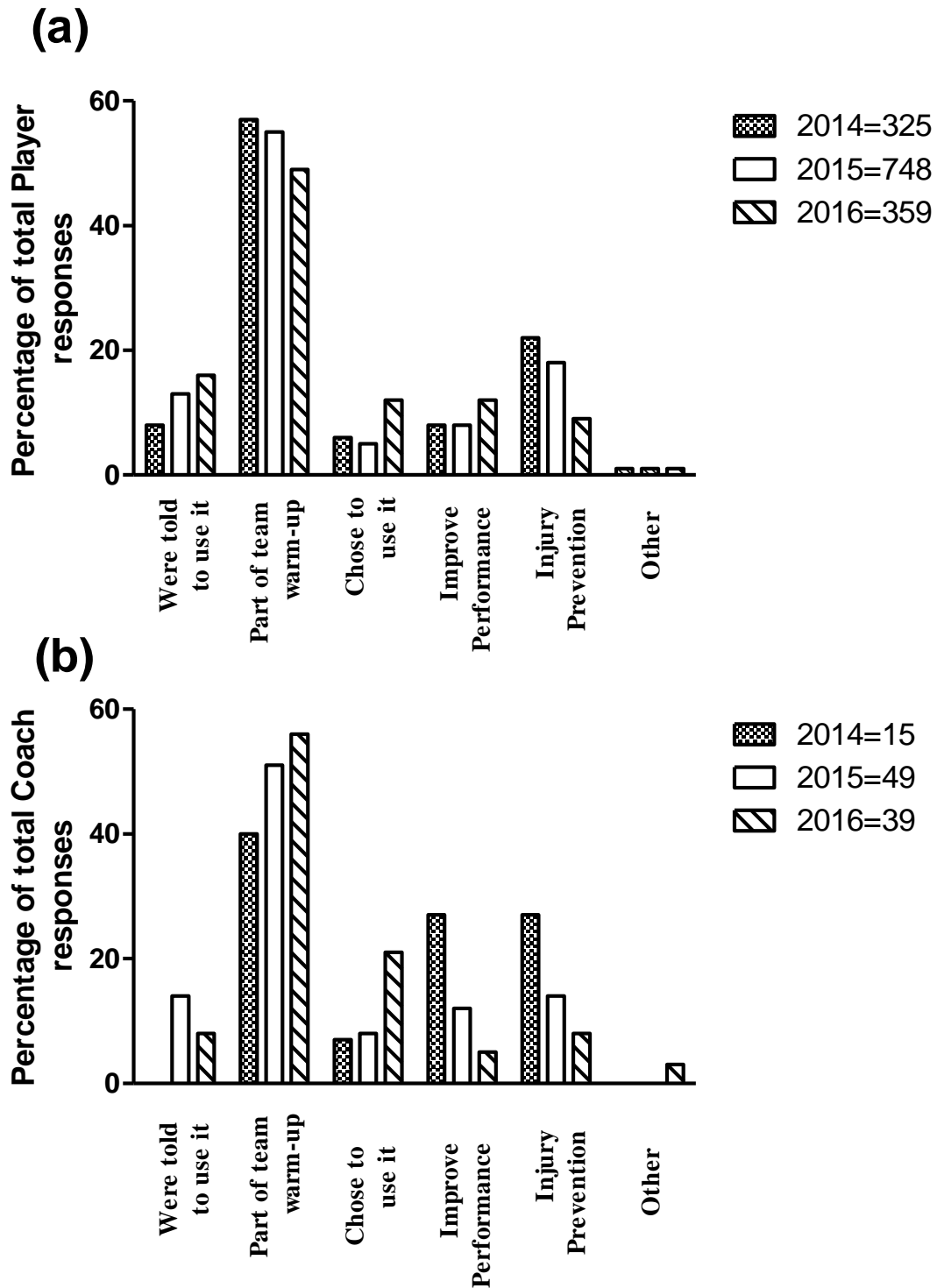


Figure 4.2a): Players' who claimed to use the exercises, these are their responses to the question "Why did you use the BokSmart Safe Six exercises?" (participants could tick multiple options). b) Coaches' who claimed to use the exercises, these are their responses to the question "Why did you use the BokSmart Safe Six exercises?" (participants could tick multiple options).

The largest number of participants reported using the Safe Six because it was "part of their team warm-up" (over all the years) (Figure 4.2).

Discussion

The primary aim of the study was to determine the change in the knowledge of coaches and players of the *Safe Six* programme, compared to the launch year, following a targeted marketing approach. Overall there were significant changes in the awareness and knowledge of the coaches' and players' of the BokSmart *Safe Six* injury prevention programme. Furthermore, there was a significant relationship between the knowledge and awareness of coaches and their respective players. This finding supports BokSmart's coach-targeted approach.

Awareness of the *Safe Six* increased in 2015 and 2016 compared to 2014, in coaches and players following the targeted marketing period. The coaches' knowledge and awareness of the *Safe Six* was significantly higher than that of the players', which was to be expected because BokSmart as a whole and specifically the *Safe Six* is a coach-targeted programme.[7] Furthermore, when comparing the coaches' knowledge and awareness to their respective players' knowledge and awareness, there was a significant relationship in the marketing year, indicating that the coach-driven approach was effective in knowledge transfer to the players. Furthermore, when considering the reported use of the exercises, in 2016 more than half of the players reported not using the exercises, whereas the majority of coaches reported that they did use the exercises. Whilst the question might over-estimate the implementation of the exercises, either the coaches are showing social desirability bias or the knowledge transfer from coach to player appears to have decreased. If it is the latter, at least the exercises are still being implemented. This relationship, and the consequences of this relationship has been illustrated in other studies in rugby. In New Zealand, RugbySmart is a coach-targeted programme, which has been associated with an increase in injury preventing behaviours in players, as well as a decrease in injury claims per 100 000 players.[8] In South Africa, the BokSmart programme as a whole has also been associated with positive changes in injury prevention behaviours in the players.[10] Other more specific exercise-based injury prevention programmes have also been coach-targeted, with their results indicating a preventive effect (in certain areas, not overall injuries) for the players.[14, 15] These programmes indicate that coach-targeted programmes have the desired effect on the players they are trying to reach.

However, when further analysing the fidelity of knowledge of the coaches and players of the *Safe Six*, their ability to name the exercises was poor, compared to the total number of participants. Therefore, if the *Safe Six* is a programme important to BokSmart, and is potentially

effective in preventing injuries,[13] it is suggested that BokSmart continues to perform the marketing measures on an annual basis (more than just incorporated into the current BokSmart biennial courses)[7] to reach the target audiences and to increase the use of the programme.

As mentioned above, the *Safe Six* programme was designed as an injury prevention programme, but exploring the arguments as to why players and coaches implement the exercises is important to understand. The explanations for use of the *Safe Six* programme were predominantly for the warm-up in both the players and coaches, however, the second most popular explanation for players was injury prevention and for coaches was to improve performance. The programme was designed to be incorporated into the warm-up as an injury prevention programme, and therefore is being used as intended. However, there could also be a “misconception” between coaches that the *Safe Six* is a performance enhancement programme, instead of an injury prevention programme. It must be noted that a significant number of both the coaches and players perceived the *Safe Six* to be easy to use (which was BokSmart’s goal when designing the programme), which therefore did not hamper their experiences regarding the programme.

The source of information varied between coaches and players. The coaches reported receiving most of their information from social media/news. Coaches received communication from their respective provincial unions who are governed by SARU, and therefore this relationship was expected. Social media/news were especially targeted in the marketing period using mostly the Twitter and Facebook BokSmart accounts (2996 and 4065 followers respectively) (April 2017). For the players, most heard of the *Safe Six* from their coaches. The next popular source of hearing about the programme was from social media/news. This raises an interesting method of communicating for injury prevention awareness. The method was free and proved effective in reaching both the coaches and players. Social media and phone applications have become a new form of implementation for injury prevention programmes.[16, 17] In a review of phone-based injury prevention applications there were eighteen applications which claimed to have sports or health benefits.[16] The applications, however did not all include evidence to support their programmes, but still exist as injury prevention measures. Such findings indicate a shift towards the technology-based form of injury prevention methods. Whilst these applications may not all have been based on scientific principles, they still attract attention.

While technology-based reach can be high, full utilization may be low. For example, an application focused on reducing ankle sprains had 24 360 unique users, the average usage was

3.3 App sessions, compared to the prescribed 24 sessions that the ankle programme consisted of, illustrating a low compliance once downloaded.[17] Therefore targeted efforts are required to ensure that the programme is used appropriately.[17] This principle could also be applied to the *Safe Six* where the reach and usage increased during the marketing period (possibly because of the social media exposure), and then decreased post-marketing. This is important knowledge for BokSmart and how they continue to disseminate knowledge regarding the *Safe Six* and future initiatives.

Limitations

This was a cross-sectional study with self-reported knowledge, usage and exposure. Therefore, the results must be interpreted in this context. 44% of players could not be linked to a coach to determine the player/coach knowledge transfer, and this must be considered when interpreting those results. It must be noted that the percentage of repeat players completing the questionnaire in subsequent years is assumed to be minimal (as with all studies using the SARU youth week rugby tournaments as the cohort), however the coaches have never been assessed and there could be more repeat participants.[18-22]

Conclusion

The knowledge and awareness of the BokSmart *Safe Six* of both players and coaches increased in 2015 and 2016 (compared to 2014) since the launch of the programme, however, did slightly decrease during the post-marketing period. The coaches reported receiving their information regarding the *Safe Six* from the Unions/SARU and social media/news. The information for the players, came from the coaches and social media/news. Reported usage of the programme increased in 2015 (i.e. the marketing period), but decreased to the pre-marketing levels in 2016. Finally the reasons for using the programme were predominantly for the warm-up, injury prevention and for performance improvements. The information gathered in this study will help with designing targeted marketing for future programmes and for further promotion of the BokSmart *Safe Six*. It also provides insight into the perceptions of the coaches and players regarding the *Safe Six* and therefore allows for BokSmart to make adjustments accordingly.

References

1. Brooks J, Kemp S. Recent trends in rugby union injuries. *Clin Sports Medicine*. 2008;51-73.
2. Hootman JM, Dick R, Agel J. Epidemiology of Collegiate Injuries for 15 Sports: Summary and Recommendations for Injury Prevention Initiatives. *J Athl Train*. 2007;42(2):311-19.
3. Williams S, Trewartha G, Kemp S, Stokes K. A meta-analysis of injuries in senior men's professional Rugby Union. *Sports Med*. 2013;43(10):1043-55.
4. Australian Rugby Union. Key points for the tackler and ball-carrier, Australian Rugby Union SmartRugby: Confidence in contact. A guide to the SmartRugby Program. 2008:18-19.
5. New Zealand Rugby Union. Technique: the key factors in the tackle and taking the ball into contact. *RugbySmart 2007: A guide to injury prevention for peak performance.*, 2007:12-14.
6. SA Rugby. BokSmart: safe and effective techniques in rugby - practical guidelines., 2009.
7. Viljoen W, Patricios J. BokSmart – implementing a National Rugby Safety Programme. *Br J Sports Med*. 2012;46(10):692-93.
8. Gianotti SM, Quarrie KL, Hume PA. Evaluation of RugbySmart: A rugby union community injury prevention programme. *J Sci Med Sport*. 2009;12(3):371-75.
9. Quarrie KL, Gianotti SM, Hopkins WG, Hume PA. Effect of nationwide injury prevention programme on serious spinal injuries in New Zealand rugby union: ecological study. *BMJ*. 2007;334(7604):1150.
10. Brown JC, Gardner-Lubbe S, Lambert MI, Van Mechelen W, Verhagen E. The BokSmart intervention programme is associated with improvements in injury prevention behaviours of rugby union players: an ecological cross-sectional study. *Inj Prev*. 2015;21(3):173-78.
11. Brown JC, Gardner-Lubbe S, Lambert MI, van Mechelen W, Verhagen E. Coach-directed education is associated with injury-prevention behaviour in players: an ecological cross-sectional study. *Br J Sports Med*. 2016: 10.1136/bjsports-2016-096757.
12. Brown JC, Verhagen E, Knol D, Van Mechelen W, Lambert MI. The effectiveness of the nationwide BokSmart rugby injury prevention program on catastrophic injury rates. *Scand J Med Sci Sports*. 2016;26(2):221-25.
13. Sewry N, Verhagen E, Lambert M, van Mechelen W, Brown J. Evaluation of the effectiveness and implementation of the BokSmart Safe Six Injury Prevention Programme: a study protocol. *Inj Prev*. 2017;23:428.
14. Finch CF, Twomey DM, Fortington LV, et al. Preventing Australian football injuries with a targeted neuromuscular control exercise programme: comparative injury rates from a training intervention delivered in a clustered randomised controlled trial. *Inj Prev*. 2015:injuryprev-2015.
15. Hislop M, Stokes K, Williams S, et al. The efficacy of a movement control exercise programme to prevent injuries in youth rugby: a cluster-randomised controlled trial. *Br J Sports Med*. 2017;51(4):330-31.
16. van Mechelen DM, van Mechelen W, Verhagen EALM. Sports injury prevention in your pocket?! Prevention apps assessed against the available scientific evidence: a review. *Br J Sports Med*. 2014;48(11):878-82.
17. Vriend I, Coehoorn I, Verhagen E. Implementation of an App-based neuromuscular training programme to prevent ankle sprains: a process evaluation using the RE-AIM Framework. *Br J Sports Med*. 2015;49(7):484-88.
18. Brown J, Verhagen E, Viljoen W, et al. The incidence and severity of injuries at the 2011 South African Rugby Union (SARU) Youth Week tournaments. *S Afr J Sports Med*. 2012:49-54.

19. Burger N, Lambert MI, Viljoen W, et al. Mechanisms and factors associated with tackle-related injuries in South African Youth Rugby Union players. *Am J Sports Med.* 2017;45(2):278-85.
20. Burger N, Lambert MI, Viljoen W, Brown JC, Readhead C, Hendricks S. Tackle-related injury rates and nature of injuries in South African Youth Week tournament rugby union players (under-13 to under-18): an observational cohort study. *BMJ Open.* 2014;4(8).
21. Burger N, Lambert MI, Viljoen W, Brown JC, Readhead C, Hendricks S. Tackle technique and tackle-related injuries in high-level South African Rugby Union under-18 players: real-match video analysis. *Br J Sports Med.* 2016;50(15):932-38.
22. Mc Fie S, Brown J, Hendricks S, et al. Incidence and Factors Associated With Concussion Injuries at the 2011 to 2014 South African Rugby Union Youth Week Tournaments. *Clin J Sport Med.* 2016;26(5):398-404.

CHAPTER 5:

EFFICACY OF THE BOKSMART *SAFE SIX* INJURY PREVENTION PROGRAMME ON INJURY RISK PROFILES IN HEALTHY ADULTS; A PILOT STUDY.

Abstract

Background

Exercise-based injury prevention programs have successfully reduced injury risk profiles in many sports. The BokSmart *Safe Six* exercise-based injury prevention program was designed to reduce injuries in rugby players by reducing their injury risk profiles. The aim was to determine the efficacy of the BokSmart *Safe Six* exercise program on injury risk profiles in well-trained (but not rugby playing) individuals.

Methods

A study of eight-weeks (control and intervention four weeks each), based on a power calculation for Functional Movement Screening (FMS). Twelve healthy male non-rugby playing subjects (18 – 30 years) were recruited, who served as their own control subjects. Participants performed the BokSmart *Safe Six* exercises three times a week for four weeks. Outcome measures were: FMS sum and individual scores, Mobility and Stability (EMS) sum and individual scores and musculoskeletal screening scores, pre-control, post-control/pre-intervention and post-intervention. Changes were compared between the control and intervention periods using a Wilcoxon ranked sign test.

Results

Ten participants completed the study. Following the intervention, four individual injury risk profile scores showed a significant ($p < 0.05$) improvement in the score for: right ankle dorsiflexion lunge, left active knee extension, sit-and-reach (all musculoskeletal) and single leg hurdle step (from FMS). However, the FMS and EMS composite scores did not change.

Conclusion

The BokSmart *Safe Six* exercises improved some of the individual injury risk profiles scores in healthy male adults. Further investigation is warranted in rugby players, for whom the intervention was originally designed, assessing the effect on injury risk.

Introduction

Rugby union (hence referred to as ‘rugby’) is a contact sport, played in over 120 countries at professional and amateur levels.[1] It has a relatively high injury incidence for senior professional rugby players of 3 injuries per 1,000 player hours during training and 81 injuries per 1,000 player hours in matches.[2] Although injury incidence decreases with younger age groups, even at youth levels the incidence is higher than most other sports.[3, 4] Consequently, injury prevention interventions such as SmartRugby (Australia)[5] RugbySmart (New Zealand)[6] and BokSmart (South Africa)[7] have been developed. All these injury prevention programs focus on the management of injuries and safe playing techniques to be taught by coaches. The BokSmart program has been associated with significant improvements in players’ injury-preventing behaviours,[8] as well as a decrease in catastrophic injuries in youth rugby players.[9]

In rugby, to date the most effective exercise based intervention was developed by the English Rugby Football Union, and was shown to be effective in decreasing concussion injury incidence and injury burden.[10] Arguably, the FIFA 11+ program is the most described and widely used effective exercise-based injury prevention program in a single sport. This program has been associated with a decrease in varying types of football injuries in both female and male players at various levels and ages.[11] Another commonly used effective intervention exercise is the addition of Nordic hamstring exercises to warm-up routines.[12] In footballers especially, this intervention has decreased the incidence of hamstring injuries (both new and recurrent).[13] Based on these studies in football it is plausible to assume that an exercise-based injury prevention program would be beneficial to rugby players.

This led to South African rugby (SA Rugby) and BokSmart developing the *Safe Six* warm-up program with the goal of preventing injuries. The program consists of injury prevention exercises specifically targeting at body regions which are commonly injured during rugby; i.e. the shoulder, hamstring, lower limb and ankle.[2] The focus of the exercises is on improving motor control through improved joint stability, muscle strength, balance, with the long-term goal of reducing injury rate and severity. However, before implementing the BokSmart *Safe Six* in the rugby playing community it is important to determine the efficacy of the included exercises in a controlled study. Moreover, it is important to know whether the included exercises have the intended effect on motor control before a trial can evaluate the preventive effectiveness of *Safe Six*. The association between motor control measures and injury risk has

been established in the literature, by which motor control outcomes can be used as a proxy for injury.[14-16] Assessments of motor control, linked to injury risk, can be referred to as injury risk profiles.[14-16] As such, the aim of this study is to determine in a controlled setting the efficacy of the BokSmart *Safe Six* exercise program on motor control in healthy non-rugby playing individuals.

Methods

Study Design

Participants were their own control for the first four weeks, after which they performed the intervention three times a week (instructed by a trained instructor) for the next four weeks. Participants were eligible for participation in the study if they were male, between the ages of 18 – 30 years old, reported to be healthy and had not sustained a severe injury (>28 days lost from sporting participation) for twelve months prior to recruitment. All participants provided written informed consent and the study was granted ethical approval by the Human Research Ethics Committee of the University of Cape Town.

Sample Size

Twelve participants were recruited for the study. A standard sample size equation was used to determine the sample size following Hayes (1999),[17] using data from Bodden *et al.* (2015).[18]

$$n = (Z_{\alpha/2} + Z_{\beta})^2 (\sigma_0^2 + \sigma_1^2) / (\mu_0 - \mu_1)^2$$

n = number of participants, $\sum_{\alpha/2}$ (95%) = 1.96, \sum_{β} (90%) = 1.28, π_0 (mean FMS score of control) = 14.8, π_1 (mean FMS score of intervention, based on 15% increase) = 17.0, σ_0 (standard deviation in the absence of the intervention) = 1.21, σ_1 (standard deviation in the absence of the intervention) = 1.43.

Based on this calculation eight participants would provide sufficient statistical power. We, however, recruited twelve participants to accommodate a possible 50% drop-out rate.

Safe Six intervention

The *Safe Six* exercises are designed to be executed as part of the players' regular warm-up. They were somewhat challenging for the players, but not too time consuming and therefore did not interfere with their regular training routine. Also, the exercises are easy to implement and

do not require any equipment. The *Safe Six* consists of six exercises, of which four focus on the lower limbs (Appendix I).

Outcome Measures

Participants were tested three times throughout the study: (1) before the control period, (2) after the four-week control period, and (3) after the four-week intervention period. The testing provided a pre-post measurement for the control period (measurement 1 and 2), as well as for the intervention period (measurement 2 and 3) (Figure 5.1).

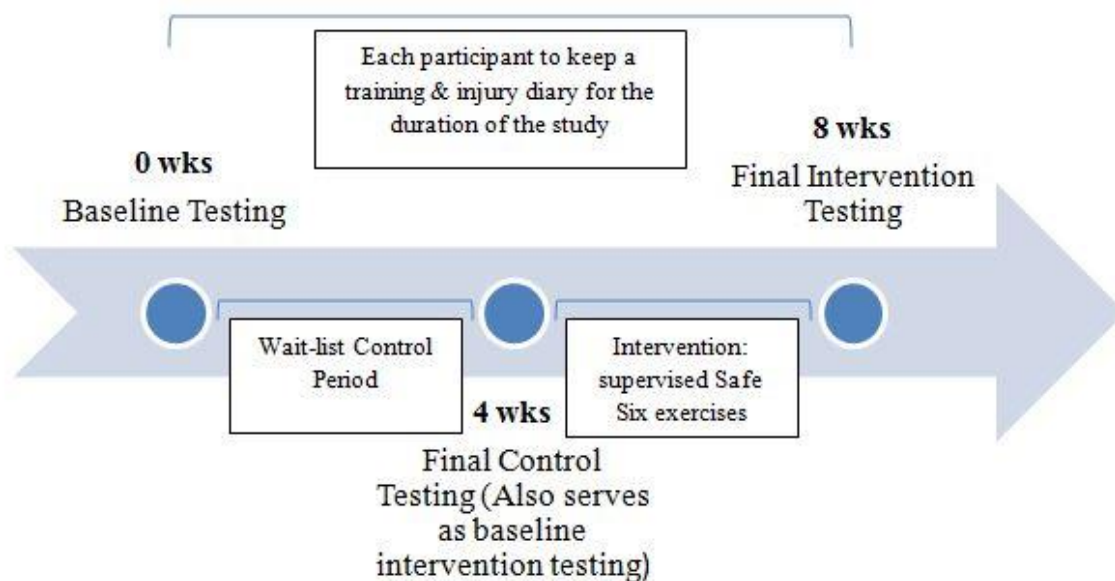


Figure 5.1: Graphic representation of study design. wks = weeks

At baseline, body height, body weight and body fat percentage (using sum of skinfolds) were measured.[19] Participants also recorded any other physical activity they had performed (other than the *Safe Six* exercises) on a paper-based training diary during the eight-week study period. The participants provided this diary to the researchers at both the second and third testing session (four-week intervals). Participants were instructed to perform only their usual physical activity during the full eight-week study. There was no warm-up before any of the testing.

For this study, injury risk profiles were assessed using Functional Movement Screening (FMS), Evaluation of Mobility and Stability (EMS) and nine separate Musculoskeletal Screening Assessments that were not covered in the FMS and EMS. These nine Musculoskeletal Screening Assessments were decided upon prior to testing, in consultation with the intervention

developers (i.e. SA Rugby). All tests were performed by two trained professionals, one of which was FMS Level 1 accredited.

The FMS has been widely documented, and the EMS is a modified version where the rotary stability test has been replaced with a seated rotation test (for the testing, only the seated rotation test was added).[20, 21] The FMS and EMS each have a composite score out of 21 arbitrary units, with seven individual assessments. Each individual assessment is rated on a 4-point scale (0 through 3).[21]

Nine Musculoskeletal Screening Assessments were added to assess the range of motion (active knee extension, modified Thomas test, active internal and external hip rotation, shoulder internal and external rotation; unit: degrees of rotation), stability (multiple hop test; time in seconds) and flexibility (ankle dorsiflexion lunge, sit and reach, lumbar spine extension and forward flexion; centimeters).[22-28]

Statistical Analysis

Descriptive statistics were calculated, using IBM SPSS Statistics 23 (2015). The matched data of the control period and the intervention period were compared, using the Wilcoxon ranked sign test. The Wilcoxon ranked sign test was used, as the outcome measures were not normally distributed. The difference scores were calculated as follows: post-control test scores values minus pre-control test scores (test 2 minus test 1) compared to post-intervention test scores minus pre-intervention test scores (test 3 minus test 2). Statistical significance was accepted at the 95% confidence level.

Results

Study sample

Ten of the twelve participants recruited for the study completed the trial (one participant withdrew due to work commitments and one sustained an injury not related to the trial). The sample had a mean body height of 181 ± 8 cm, mean body mass 78.7 ± 8.2 kg and mean body fat percentage of 13.3 ± 3.3 %. Every participant performed the exercises three times a week for the four-week intervention.

Injury Risk Profiles

The intervention of the BokSmart *Safe Six* was associated with a significant change in some of the individual scores; the right Ankle dorsiflexion lunge score, left active knee extension score,

and sit and reach score improved significantly (Table 5.1). Of the FMS and EMS test, only single leg hurdle step score improved significantly between the control and the intervention period (Supplementary Table 5.1). None of the other scores changed significantly, including the FMS and EMS composite scores.

Table 5.1: Change (Δ) in injury risk profile measures in the control and intervention periods. Values are medians (interquartile ranges) ($n=10$). Assessments were measured in degrees, except for the Ankle dorsiflexion lunge, Sit and reach and Lumbar extension/flexion, which are measured in millimetres and the Multiple hop test, which is recorded in seconds. EMS and FMS are displayed in arbitrary units.

Measure	Control (Δ)	Intervention (Δ)	p-value
Composite FMS score	1 (-1 - 2)	2 (0 - 2)	0.47
Composite EMS score	1 (0 - 2)	2 (0 - 3)	0.29
Active knee extension left	13 (9 - 19)	-4 (-15 - 2)	0.05
Active knee extension right	5 (2 - 17)	-9 (-13 - -4)	0.06
Modified thomas test knee left	-2 (-12 - 4)	1 (-7 - 6)	0.22
Modified thomas test knee right	1 (-7 - 3)	-1 (-3 - 4)	0.88
Modified thomas test hip left	-2 (-3 - 1)	1 (-2 - 4)	0.26
Modified thomas test hip right	0 (-3 - 3)	2 (1 - 3)	0.29
Active hip internal left	0 (-5 - 4)	-3 (-4 - 3)	0.51
Active hip internal right	0 (-4 - 3)	3 (2 - 4)	0.14
Active hip external left	-5 (-7 - 4)	2 (-4 - 4)	0.20
Active hip external right	4 (-10 - 11)	4 (0 - 7)	0.68
Ankle dorsiflexion lunge left	-26 (-33 - -20)	7 (-2 - 10)	0.06
Ankle dorsiflexion lunge right	-31 (-39 - -19)	2 (-5 - 7)	0.02
Sit and reach	19 (-3 - 29)	-18 (-30 - -4)	0.05
Lumbar spine extension	3 (-12 - 15)	6 (-11 - 19)	0.96
Lumbar forward flexion	0 (-30 - 0)	0 (0 - 0)	0.11
Shoulder rotation internal left	2 (-16 - 8)	5 (-8 - 11)	0.72
Shoulder rotation internal right	-1 (-4 - 8)	8 (-7 - 17)	0.41
Shoulder rotation external left	-3 (-5 - 8)	-1 (-5 - 7)	0.92
Shoulder rotation external right	-1 (-6 - 3)	1 (-3 - 4)	0.81
Multiple hop test left	-6 (-9 - -2)	-6 (-9 - -1)	0.72
Multiple hop test right	-5 (-6 - -1)	-4 (-8 - -2)	0.86

Discussion

The aim of this study was to determine the efficacy of the BokSmart *Safe Six* exercise program on motor control in healthy non-rugby playing individuals in a controlled setting. The BokSmart *Safe Six* exercises elicited an improvement in four of the injury risk profile scores (17% of the assessments). However, there were no changes in the FMS and EMS composite scores.

Looking closer at the individual FMS and EMS scores, the single leg hurdle step individual score did improve significantly. This was unexpected, as comparable exercise programs have been associated with changes in FMS scores previously. A study by Bodden et al. (2015) illustrated that a four-week intervention program was sufficient to improve FMS scores among a group of Mixed Martial Arts participants.[18] Moreover, Kiesel et al. (2011) found that a seven-week exercise-based program for professional football players improved the FMS composite score.[15] Both studies used corrective programs, based on the individual's FMS results as the exercise-based intervention.[18, 15] These studies are examples, showing that the FMS and EMS are sensitive to intervention-related change over a short period of time. However, the participants recruited for the study already had high composite FMS and EMS scores, with a median of 16 at baseline (test 2) for both. Males from the general population have a lower mean composite FMS score of 14.8; this could explain the lack of change in response to this four-week intervention.[29] Therefore, on average, participants were scoring at least a two (out of a possible three) on each individual FMS/EMS assessment. To improve from a score two to a three on the FMS and EMS is difficult, as a score of three is only awarded if the movement is performed without any compensation and flawlessly. This is not as attainable, as a score of two indicates compensations and/or a correction during the movement evaluation. Thus, the lack of improvement in the present study might be more related to the subjectivity of the FMS and EMS scoring system.

However, the BokSmart *Safe Six* did show an improvement in three out of the nine separate Musculoskeletal Screening Assessment scores. The ankle dorsiflexion lunge, which measures the flexibility of the ankle in one plane, showed a significant change in score after the intervention. Specific exercises from the BokSmart *Safe Six* such as the 'Six' Dynamic Reaches, the 'Six'-Meter Shuttle-Runs, could have explained this effect on the ankle dorsiflexion lunge test (however it is strange that it is only in one limb). Similarly, a variety of

lunges (the ‘Six’-Point Lunge and ‘Six’-Bok Lunge) was also performed throughout the intervention.

Similarly, the active knee extension assessment score improved. This finding could be explained by the involvement of the quadriceps and hamstring muscle groups in many of the *Safe Six* exercises, such as the ‘Six’-Point lunge, the ‘Six’-Bok lunge and the Butt-Smart ‘Six’ (Appendix I). During the active knee extension test, the quadriceps and hamstrings are actively recruited and de-activated to maintain the leg in the air. The exercises may have increased the strength of these muscle groups resulting in the improvement post-intervention.

Lastly, the sit and reach test score also improved following the intervention. The sit and reach test has been used as a predictor of relative risk for a hamstring injury.[26] A study by Gabbe *et al.* (2006) on elite football players indicated that an increased sit and reach score, therefore increased flexibility of the hamstring group and/or lumbar spine, was associated with a higher risk of subsequent hamstring compared to a reduced score.[26] These changes could have been elicited through a similar mechanism to that occurring in the Active knee extension.

It is important to note that the study design considered the possibility of a learning effect by comparing the changes and not absolute values. However, this “learning effect” cannot be completely accounted for, and therefore could be a confounder. For example, the multiple hop test score steadily improved with the three testing sessions, even after the control period, which could indicate evidence of a learning effect. The subjects were exposed to the testing protocol three times, and therefore they might have ‘learned’ the protocol by the third, and final testing, and the short test-retest period (four weeks) could have also facilitated a learning effect.

The BokSmart *Safe Six* exercises improved several of the individual assessment scores, but no change in FMS/EMS composite scores, from the injury risk profiles. This study is one of the first to look at these factors as a precursor to injury. Using this information, further inferences regarding the effectiveness of the exercises on injury risk profiles and injury rates, and the association between the injury risk profiles and injury rates in real-world contexts can be made.[30]

Limitations

The sample included well-trained, healthy adults, with established training habits. Younger participants may have produced slightly different results to that of the current sample as a result of passing through adolescence. The lack of a familiarisation period for some of the tests could

have been a limitation, although the study design did attempt to reduce the effect of this by only comparing the change in control versus the change in intervention period and not absolute values. A limitation could be that we did not conduct an RCT. Although the duration of the intervention was justified by previous research with FMS composite score as an outcome, it would be interesting to see what a longer intervention period would elicit.

Conclusion

The BokSmart *Safe Six* exercises had a positive effect on four of the Musculoskeletal Screening Assessments scores (active knee extension, ankle dorsiflexion lunge, sit and reach and an individual FMS score). Neither the FMS nor EMS composite scores changed in this study. Future studies should now be conducted with youth rugby players, with a familiarisation session and longer intervention period. This short intervention indicates a possibility of positive results if implemented with youth rugby players in a real-world context.

References

1. Meir R, Halliday A. Pre- and post-game body mass changes during an international rugby tournament: a practical perspective. *J. Strength Cond. Res.* 2005;19:713-16.
2. Williams S, Trewartha G, Kemp S, Stokes K. A meta-analysis of injuries in senior men's professional Rugby Union. *Sports Med.* 2013;43(10):1043-55.
3. Hootman JM, Dick R, Agel J. Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. *J Athl Train.* 2007;42(2):311-19.
4. Mc Fie S, Brown J, Hendricks S, et al. Incidence and factors associated with concussion injuries at the 2011 to 2014 South African Rugby Union Youth Week tournaments. *Clin J Sport Med.* 2016;26(5):398-404.
5. Australian Rugby Union. Key points for the tackler and ball-carrier, Australian Rugby Union SmartRugby: Confidence in contact. A guide to the SmartRugby Program. 2008:18-19.
6. New Zealand Rugby Union. Technique: the key factors in the tackle and taking the ball into contact. *RugbySmart 2007: A guide to injury prevention for peak performance.* 2007:12-14.
7. SA Rugby. BokSmart: safe and effective techniques in rugby - practical guidelines. 2009.
8. Brown JC, Gardner-Lubbe S, Lambert MI, Van Mechelen W, Verhagen E. The BokSmart intervention programme is associated with improvements in injury prevention behaviours of rugby union players: an ecological cross-sectional study. *Inj Prev.* 2015;21(3):173-78.
9. Brown JC, Verhagen E, Knol D, Van Mechelen W, Lambert MI. The effectiveness of the nationwide BokSmart rugby injury prevention program on catastrophic injury rates. *Scand. J Med Sci Sports.* 2016;26(2):221-25.
10. Hislop MD, Stokes KA, Williams S, et al. Reducing musculoskeletal injury and concussion risk in schoolboy rugby players with a pre-activity movement control exercise programme: a cluster randomised controlled trial. *Br J Sports Med.* 2017;51:1140-6.
11. Barengo NC, Meneses-Echávez JF, Ramírez-Vélez R, Cohen DD, Tovar G, Bautista JEC. The impact of the FIFA 11+ training program on injury prevention in football players: a systematic review. *Int J Environ Res Public Health.* 2014;11(11):11986-12000.
12. Brooks JH, Fuller CW, Kemp SP, Reddin DB. Incidence, risk, and prevention of hamstring muscle injuries in professional rugby union. *Am J Sports Med.* 2006;34(8):1297-306.
13. Petersen J, Thorborg K, Nielsen MB, Budtz-Jørgensen E, Hölmich P. Preventive effect of eccentric training on acute hamstring injuries in men's soccer a cluster-randomized controlled trial. *Am J Sports Med.* 2011;39(11):2296-303.
14. Filipa A, Byrnes R, Paterno MV, Myer GD, Hewett TE. Neuromuscular training improves performance on the Star Excursion Balance Test in young female athletes. *J Orthop Sports Phys Ther.* 2010;40(9):551-8.
15. Kiesel K, Plisky P, Butler R. Functional movement test scores improve following a standardized off-season intervention program in professional football players. *Scand J Med Sci Sports.* 2011;21(2):287-92.
16. Tee JC, Klingbiel J, Collins R, Lambert M, Coopoo Y. Preseason Functional Movement Screen component tests predict severe contact injuries in professional rugby union players. *J Strength Cond Res.* 2016;30(11):3194-203.
17. Hayes RJ, Bennett S. Simple sample size calculation for cluster-randomized trials. *Int J Epidemiol.* 1999;28(2):319-26.
18. Bodden JG, Needham RA, Chockalingam N. The effect of an intervention program on Functional Movement Screen test scores in Mixed Martial Arts Athletes. *J Strength Cond Res.* 2015;29(1):219-25.

19. Durnin J, Womersley J. Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged 16 to 72 years. *Br J Nutr.* 1974;(32):77-97.
20. Cook G, Burton L, Hoogenboom B. Pre-participation screening: the use of fundamental movements as an assessment of function – Part 1. *N Am J Sports Phys Ther.* 2006;1(2):62-72.
21. Cook G, Burton L, Hoogenboom B. Pre-participation screening: The use of fundamental movements as an assessment of function – Part 2. *N Am J Sports Phys Ther.* 2006;1(3):132-9.
22. Brukner P, Khan KM. Low back pain. In: *Clinical Sports Medicine.* McGraw Hill Companies Inc. 2001(2nd eds.):330-59.
23. Cools AM, De Wilde L, Van Tongel A, Ceysens C, Ryckewaert R, Cambier DC. Measuring shoulder external and internal rotation strength and range of motion: comprehensive intra-rater and inter-rater reliability study of several testing protocols. *J Shoulder Elbow Surg.* 2014;23(10):1454-61.
24. Dennis RJ, Finch CF, Elliott BC, Farhart PJ. The reliability of musculoskeletal screening tests used in cricket. *Phys Ther Sport.* 2008;9(1):25-33.
25. Eecheute C, Vaes P, Duquet W. Functional performance deficits in patients with CAI: validity of the multiple hop test. *Clin J Sport Med.* 2008;18(2):124-9.
26. Gabbe BJ, Bennell KL, Finch CF, Wajswelner H, Orchard JW. Predictors of hamstring injury at the elite level of Australian football. *Scand J Med Sci Sports.* 2006;16(1):7-13.
27. Gabbe BJ, Bennell KL, Wajswelner H, Finch CF. Reliability of common lower extremity musculoskeletal screening tests. *Phys Ther Sport.* 2004;5(2):90-7.
28. Lin J-j, Yang J-L. Reliability and validity of shoulder tightness measurement in patients with stiff shoulders. *Man Ther.* 2006;11(2):146-52.
29. Kraus K, Schutz E, Taylor W, Doyscher R. Efficacy of the functional movement screen: a review. *J Strength Cond Res.* 2014;28(12):14.
30. Sewry N, Verhagen E, Lambert M, van Mechelen W, Brown J. Evaluation of the effectiveness and implementation of the BokSmart Safe Six injury prevention programme: a study protocol. *Inj Prev.* 2017;23:428.

Supplementary 5.1: FMS and EMS individual scores. Values are medians (interquartile ranges) (n=10).

Measure (AU)	Control (Δ)	Intervention (Δ)	p-value
Overhead squat	0 (0 – 0)	0 (0 – 1)	0.33
Single leg hurdle step	0 (0 – 0)	1 (0 – 1)	0.03
Split lunge	0 (-1 – 1)	0 (0 – 1)	0.38
Shoulder mobility	0 (0 – 1)	0 (0 – 0)	0.32
Active straight leg raise	0 (0 – 0)	0 (0 – 0)	0.16
Stability push up	0 (0 – 0)	0 (0 – 1)	0.66
Seated rotation (EMS)	0 (0 – 0)	0 (0 – 0)	0.32
Rotary stability (FMS)	0 (0 – 0)	0 (0 – 0)	1.00

CHAPTER 6:

EVALUATION OF THE EFFECTIVENESS AND IMPLEMENTATION OF THE BOKSMART *SAFE SIX* INJURY PREVENTION PROGRAM: A STUDY PROTOCOL

Published as:

Sewry, Verhagen, Lambert, van Mechelen, Brown. Evaluation of the Effectiveness and Implementation of the BokSmart Safe Six Injury Prevention Programme: a study protocol. *Injury Prevention*, 2017;23:428

Abstract

Background

The injury risk in rugby union ('rugby') is high. While exercise-based injury prevention programmes have successfully reduced injuries in other sports such as football, there is minimal research on this topic in rugby union. The aim of this paper was to evaluate the effectiveness and implementation of an exercise-based intervention (BokSmart *Safe Six*) in junior rugby players that aims to reduce the injury risk profile and burden of injury.

Methods

Fourteen to sixteen-year-old Junior rugby players in two geographically separated locations in South Africa over the 2017 rugby playing season will be recruited. A cluster-randomized controlled trial where the teams are allocated to groups that either; (i) have a coach-delivered exercise intervention in their warm-up (BokSmart *Safe Six*), or (ii) continue with their warm-up 'as usual' (control group). Injury risk profiles will be assessed through musculoskeletal screening on all players performed at the beginning, middle and end of the trial. Epidemiological measurements include injury surveillance at all matches and training sessions, and exposure to the various warm-up exercises (including BokSmart *Safe Six* exercises). Behavioural determinants of coaches will be assessed through standardised theory of planned behaviour questionnaires and focus groups before and after the intervention.

Outcome measures

Comparison in injury risk profiles and burden of injury between the intervention and control groups. Changes in the behavioural determinants of coaches.

Background

The benefits of physical activity (for both health and well-being) are widely accepted,[1, 2] however, physical activity levels are still low. This lack of physical activity has created a public health burden, and therefore, due to its numerous associated benefits, physical activity has been promoted within society.[2, 1] Physical Activity (PA) promotion may have led to an increase in sporting participation, and therefore by extension, also in rugby union. An increase in PA and sporting participation, has also coincided with an increase in sports-related injuries.[3, 4] This increase in sporting injury-risk needs to be addressed. Hence, for amateur rugby union in South Africa, the development and evaluation of the BokSmart *Safe Six* exercise-based intervention.

Rugby union

Rugby union (hence referred to as ‘rugby’) is an international sport played in over 100 countries at professional and amateur levels and is particularly popular in South Africa, which has over 468 000 players (as of 2016).[5, 6] Rugby became a professional sport in 1995. Following this there was an increase in physical demands on the players.[7]

The sport of rugby is played by two teams, consisting of 15 players per team on the field at one time.[7] A rugby match is 80 minutes in duration at adult level, but youth rugby can be 70 minutes,[8] 60 minutes (U16) or 50 minutes (U13) depending on the age-group (SA Rugby Union tournaments). It must be noted that there is also another form of rugby known as “rugby league” which differs from rugby union, in that there is no line-out. There are only thirteen players per team and the ball is played immediately after each tackle.[9] In league, there is also no contest in the scrum.

Rugby is characterised by intermittent high intensity bouts of exercise and bodily collisions (known as tackles). Therefore, the requirements of each position result in varying physiological and anthropometrical differences between players.[10, 7, 11-15] The ballistic nature and high force- and momentum-generating movements occurring in rugby are associated with a high injury risk and require skill to be performed safely and effectively.[16, 17, 11, 18]

Given the contact nature of rugby, the injury incidence in senior rugby players is high, 81 (95% CI 63 – 105) injuries per 1000 match hours and 3 (95% CI 2 – 4) injuries per 1000 training hours,[19] in comparison to other sports (for instance men’s collegiate soccer in the United

States was 19 injuries per 1000 match hours).[20] Lower limbs are at greatest risk for injury, followed by the upper limbs, head and trunk. In terms of severity (time lost due to injury), the lower limb, followed by the trunk and head/neck area are reported to be the most severe.[19] In South African youth rugby the average injury incidence was 22 injuries per 1000 player hours, across age group tournaments.[21]

Every injury is also accompanied by an associated medical treatment cost, and as such, as the incidence increases so does the financial burden on both the player, their family and society.[22] The average financial burden on an injured player in South African youth rugby tournaments is high and is estimated at US\$731 per injured player.[23] Based on this information, it can be stated that the burden of a rugby injury in South Africa is high and as such prevention programmes are necessary.

Prevention of rugby injuries

This notable injury incidence in both seniors and youth rugby, shows the need for injury prevention strategies.[18] However, Freitag *et al.* (2015), have gone further to state that most prevention programmes for rugby have yet to be evaluated and therefore their effectiveness in preventing injuries is unknown.[24] Examples of such interventions are SmartRugby and RugbySmart of Australia and New Zealand, respectively.[25, 26] Within South Africa, the South African Rugby Union (SA Rugby) developed BokSmart, a program promoting evidence-based techniques for playing both safe and effective rugby, and the management of both injured and uninjured players.[27] The implementation of BokSmart and RugbySmart have both been associated with a reduction in catastrophic injuries. With the implementation of BokSmart's prevention strategies there has also been an increase or improvement in targeted injury prevention behaviours in players.[28-30]

These nationwide prevention strategies targeting primarily coaches and referees have therefore been shown to be effective. Strategic law changes, such as those implemented by SA Rugby within the scrum, have also shown positive signs in preventing injuries.[17] Law changes affect the dynamics of the game, whereas techniques taught to players to prevent injuries and improve performance, have minimal if any, impact on the nature of the game.

Tackle technique is consistently associated with both injury and performance, and the teaching and prescription of tackle technique is an important component in nationwide prevention programmes.[31, 16, 32, 14, 33] Hendricks *et al.* (2010) illustrated how the shoulder tackle, as

opposed to the arm tackle and jersey tackle, is the most effective and safest tackle for rugby players to execute. Also, a leg drive in the tackle has the potential to reduce injury risk and increase the success of the tackle.[14]

Furthermore, physical fitness and lack of conditioning of players has been linked to injury risk. Training to prepare the players for the demands of the game has become an important part of a rugby team's preparation for the season. Cohort studies in rugby league have shown that players with a heavier body mass, poorly developed intermittent high intensity running, poor upper body strength, and low maximal aerobic power have an increased risk of sustaining a contact injury.[34, 9] There is conflicting data on speed, with one study showing that faster players have a higher injury risk,[34] whilst another study claimed the opposite.[9] Many of these physical characteristics can be developed in the gym to prepare the players for the movements and demands of rugby.

Rationale for components of an effective exercise training programme

Sport-specific weight training, whether it be body weight or gym-based training, high intensity training and training changes of direction, have been associated with a decrease in hamstring injuries in Australian football players.[35] Hamstring injuries are a common injury in rugby. An exercise-based intervention was found to reduce hamstring injuries in senior professional rugby union.[36] Brooks *et al.* found that the group who had performed static stretching, a regular strengthening program, and Nordic hamstring curls, sustained a lower incidence of injuries, compared to the group who had only performed their regular strengthening program.[36] Another study with a similar design showed comparable results in Australian football players.[37]

Balance training is a training component associated with a decrease in ankle sprains. Using single limb balance on a foam pad, American football players had a decreased incidence in non-contact ankle sprains.[38] This study emphasises the need for balance training in players participating in contact sport.

Measuring an effective training programme

The Functional Movement Screen (FMS) is a screening tool of seven reliably assessed movements, which are scored out of a possible accumulated total of 21 points. A person who scores less than or equal to 14 in this assessment has a proven moderate prediction (54%) of a

non-specific time-loss injury, i.e. any injury where the athlete will miss at least one training session and/or match fixture due to the injury.[39, 40] The FMS has a moderate to good inter-rater and intra-rater reliability for novice assessors, making it an accessible assessment tool to use at any level.[39] Using the FMS to predict injury, allows for a control trial to be performed over a shorter period, as one can measure the change in outcome of this measure, even if the actual number of injuries during that period is minimal. For example, positive changes in the FMS and musculoskeletal assessments following corrective programmes have been shown in footballers and martial arts after seven and eight-week interventions respectively.[41, 42]

The BokSmart Musculoskeletal Screening Assessment was compiled by content experts using evidence-based assessments to provide an injury risk profile for a rugby player. Some tests are associated with injury risk using a range of movements for specific muscle groups. This is important as FMS does not always account for this, but these factors do contribute to injury risk. active knee extension is one test in the assessment that has been associated with an increased risk of a hamstring injury of up to 18% in a football player.[43] Similarly, the sit and reach test has been associated with an increased risk of hamstring injuries.[44] Results from the FMS and Musculoskeletal Screening Assessment will jointly be described as the injury risk profile from now on.

This paper outlines the aims, objectives and methods of the trial to evaluate the effectiveness and implementation of the BokSmart *Safe Six* exercises in youth rugby players, as an injury prevention programme. This study has been designed in accordance with the CONSORT statement.[45]

Research Aims and Hypotheses

The present BokSmart *Safe Six* study aims to:

1. Evaluate the effectiveness of the BokSmart *Safe Six* exercise program on injury rates and injury risk profiles of Under 16 male rugby players prior to and after using the BokSmart *Safe Six*
2. Evaluate how the BokSmart *Safe Six* exercises are being implemented within the school context, while examining aspects of exercise quality, including fidelity
3. Determine the barriers and facilitators to the implementation of the BokSmart *Safe Six* in the schoolboy rugby setting

Specific hypothesis is:

1. Injury risk profiles will be reduced as a result of the implementation of the BokSmart *Safe Six* exercise intervention.

BokSmart *Safe Six* intervention

After identifying injuries associated with the highest burden in rugby,[19] the BokSmart *Safe Six* intervention was designed. The BokSmart *Safe Six* programme was officially launched in 2014 as a freely available resource. The targeted areas of injury prevention are the knee, hamstring, lower limb, ankle and shoulder, which are most commonly injured and are associated with the greatest injury severity.[19] The BokSmart *Safe Six* exercises are designed to specifically target these high-risk areas of the body to increase strength, joint stability, balance and control, with the overall goal of reducing the rate and severity of injury. In particular, they were designed to optimise implementation, and also in communities who were lacking resources: i.e. they can be performed any place, any time, without requiring any equipment or facility, and are of short enough duration that it does not interfere with regular training. The exercises were also designed to be included as part of the regular team warm-up. However, BokSmart has yet to actively implement the BokSmart *Safe Six* intervention nationally.

Trial design and study arms

Trial design

Schoolboy rugby teams will be randomly assigned to either the BokSmart *Safe Six* intervention or the control group using a toss of a coin.

Control arm: control group

The control group will be required to film their warm-up routines ‘as per usual’ at every practice for analysis, to determine if they are performing any of the intervention exercises that would need to be included in the statistics as a confounder. Beyond the filming of warm-up sessions, the control teams will not receive any special instructions. It must be noted that the BokSmart programme has disseminated knowledge of the BokSmart *Safe Six* exercises widely; the exercises are freely available on the website. Therefore, contamination cannot be prevented.

Intervention arm: BokSmart *Safe Six* exercises

The intervention group will be required to incorporate the BokSmart *Safe Six* exercises designed by BokSmart into their warm-up routine.

To keep it simple and practical, and easy to remember, there is no progression of exercises over the period of the intervention.

RCT Methodology

The study is a cluster-randomised controlled trial, evaluating the exercise programme in the field, over a single playing season. A cluster-randomised design allows for a field-based intervention to decrease the chances of contamination between the groups. Additionally, a cluster design is applicable, as the intervention will need to be implemented at a team level, and not at an individual level, allowing for each team to be a cluster. Rugby is the sport that has been chosen as it has the highest injury incidence and severity, and therefore, is a priority sport for an injury prevention intervention.

The monitoring of injuries and the collection of exposure and adherence data used in this trial will be similar to those used in previous football studies;[46, 38, 35] and conform with the definitions and data collection procedures outlined in the rugby consensus statement.[47] The study will also include an evaluation of adherence to the intervention, and the determinants of behaviours of the coaches regarding the implementation of the intervention.[48-50]

Each school is considered a cluster, and multiple teams will be recruited from a single school to decrease the number of clusters required to achieve sufficient statistical power. The clusters in the intervention group and control group will be stratified geographically to avoid contamination and knowledge of the intervention.

Sample Size

The sample size calculation was calculated using a Functional Movement Screening (FMS) score as the outcome measure of interest for the following sample size calculation:[42]

$$C=1+(\sum_{\alpha^2} + \sum_{\beta})^2 [\pi_0(1-\pi_0)/n + \pi_1(1-\pi_1)/n + k^2(\pi_0^2 + \pi_1^2)] / (\pi_0 - \pi_1)^2$$

C= number of clusters, \sum_{α^2} (95%) = 1.96, \sum_{β} (90%) = 1.28, π_0 (mean FMS score of control) = 14.8, π_1 (mean FMS score of intervention, based on 30% increase) = 19.2, n (players per cluster) = 40, k (inter cluster coefficient of variation) = 0.2.

Therefore, to determine a statistically significant change in FMS risk profiles at the 95% confidence level, we would need 4 clusters (schools) in each of the control and intervention groups respectively, with a minimum of 40 players in each arm; i.e. a total of 160 players in the control group and 160 players in the intervention group.

Recruitment

The eight schools that will be targeted for this study all compete in the top school league in the targeted Province, the Western Province Rugby Union's School Premier League or Division, and are of a comparable standard and socioeconomic status, therefore, ensuring that the cohort is as homogenous as possible. The eight schools are divided geographically into the Stellenbosch/Paarl region and the Southern Suburbs region, with four teams in each region. The regions will be randomly assigned to the control and to the intervention group. These eight schools are all rugby-playing high schools and the players included in this study will be representatives of the 2017 Under 16 A or B schoolboy rugby squads (aged 14 or 15 years as of the 1st of January). All players must be injury-free for at least six-months prior to testing. Each school will therefore contribute a minimum of 40 players to the study. The level of rugby is of a high level, and these eight schools produce many of the players for the age-group provincial teams. The school's medical resources on match day are standardised by BokSmart protocols [51] and ensure that there is always medical support available. All schools have access to at least a physiotherapist for their players if necessary, and therefore in the case of injuries a diagnosis is available. The eight teams will be recruited for the 2017 rugby season, and will be monitored over eighteen weeks of rugby, approximately sixteen matches in total, running from April to August. The schools will be approached through their headmaster, head of sport, head of rugby and head Under 16 rugby coach to participate in the study. Once the school has confirmed their participation, any player selected for the initial squad will be eligible to participate and will be recruited through the school. Written assent from the player, written consent from the parent (in the case of a non-day boy, telephonic consent from the parent and then written consent from the housemaster) and written consent from the coach will be required for each participant before the study begins. This is in accordance with the South African ethical regulations and government requirements.

Blinding

True blinding is not possible in our study, as the control arm will not be receiving an intervention, however, they will not be aware of the 'true' purpose of the trial, as they will be informed that we are studying their warm-ups and how these are associated with injury rates. The intervention group cannot be blinded either, as they will be aware that they are performing the BokSmart *Safe Six* exercises and recording injury rates. The geographical separation is critical to the study design to minimise contamination of the intervention and control groups.

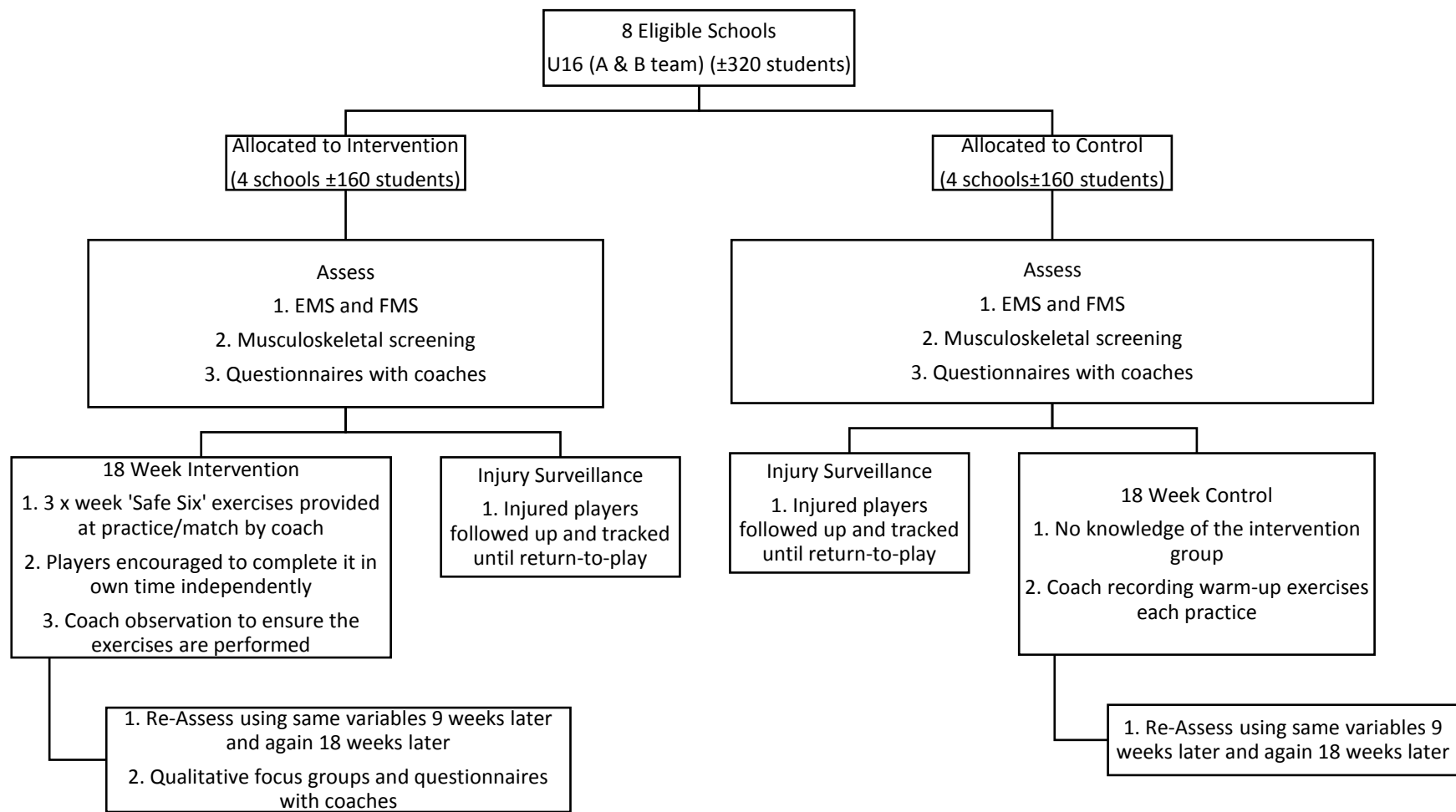


Figure 6.1: Flow diagram of the process of the cluster-randomised control trial using the BokSmart 'Safe Six'

Standardisation of Procedures

Before the trial begins, each school in the intervention group, will go through thorough training of how to implement the BokSmart *Safe Six* exercises. The coaches in the intervention group will be instructed on how to implement the exercises at practices using researcher interaction, booklets and filmed material (DVD's). The coaches will have access to the researcher at all times during the intervention if something becomes unclear. The coaches, as they will be implementing the intervention, will be required to perform the exercises to the researcher's satisfaction before beginning the trial. A "coach" is defined as a coach (i.e. biokineticist, strength and conditioning coach, general coach) who comes into contact with the players at least once a week on average over the season, therefore influencing a portion of their training or match play. Teams may have multiple coaches in which case all coaches will be included in the study

The coaches from both the control and the intervention groups will be given the same exposure (recorded during both training and matches) and adherence report forms, and be briefed on how to film the warm-ups of every practice (in the case of the control group and intervention group) and every time they perform the exercises (the intervention group, to ensure they are not performing another exercise comparable to a BokSmart *Safe Six* exercise to avoid a double dose). The head coach of each team will be the primary data collector for each team, however, he/she will not be responsible for injury data collection.

Injury data collection

The researcher will follow up on every team two days after a match to determine whether any time-loss injuries occurred. A standardised injury data collection form designed by BokSmart will be used to collect data (Appendix I). The injury definitions are aligned to the consensus statement.[47] Following an injury, the researcher will be in contact with the injured player to confirm the injury and obtain the details surrounding the injury. The player will refer the researcher on to their medical practitioner to get a diagnosis of the injury.

Every player who is injured will be followed up on a weekly basis until return-to-play to get an accurate severity score of the injury. Each school will also be visited biweekly, to collect the video footage of the training and player exposure forms. These visits will also ensure regular contact with the schools in an attempt to improve compliance. The results of each match (score) will also be recorded by the coach, as league performance has previously been associated with injury rates in rugby.[52]

Functional movement screening and musculoskeletal assessment outcomes

To determine the injury risk profile of the players, a combination of screening assessments (both functional and musculoskeletal) will be performed on every player. The FMS is the first set of assessments to be performed which consists of seven tests: 1) overhead squat; 2) single leg hurdle; 3) split squat; 4) shoulder mobility; 5) active straight leg raise; 6) stability push-up; 7) rotary stability.[53, 54] The second set of assessments is the EMS (developed at the Sports Science Institute of South Africa), which are tests 1-6 of the FMS and a seventh test: a seated rotation instead of the rotary stability. All of the FMS and EMS tests are scored subjectively using a three-point scale as described previously.[53, 54] Nine musculoskeletal assessments that are incorporated in the BokSmart Musculoskeletal Screening Assessment will be performed: 1) active knee extension (ICC of $r=0.93$ for inter-rater reliability); 2) modified Thomas test (ICC of $r=0.91-0.94$ for inter-rater reliability); 3) active internal and external range of motion of the hip (ICC of $r=0.94$ internal rotation and $r=0.88$ external rotation for inter-rater reliability); 4) ankle dorsiflexion (ICC of $r=0.99$ for inter-rater reliability); 5) sit and reach (ICC of $r=0.97$ for inter-rater reliability); 6) lumbar spine extension (ICC of $r=0.95$ for inter-rater reliability); 7) lumbar forward flexion (ICC for inter-rater reliability is unknown for this test); 8) shoulder internal and external rotation (ICC of $r=0.85-0.99$ for inter-rater reliability);[55] 9) multiple hop test (test-retest reliability was good, ICC of $r=0.91$ left ankle, $r=0.97$ right ankle in unstable, $r=0.87$ in left and right healthy ankles, the test was able to discriminate between healthy and unstable ankles).[56, 44, 57-60] Tests 1, 2, 3 and 8 are tested using a goniometer (in degrees), tests 4, 6 and 7 are tested using a tape measure (centimetres), test 5 is measured using a sit and reach box (centimetres) and test 9 is measured using a stopwatch (seconds). Anthropometrical (sum of four skinfolds, body height and body mass) and maturation status will also be assessed.[61, 62] All of the aforementioned tests will be performed on every player who participates in the study. All of the testing will be performed at the High Performance Center at the Sports Science Institute of South Africa in Cape Town. The tests will be performed before the trial begins, mid-way through the trial (nine weeks) and at the end of the trial (after eighteen weeks).

Behavioural determinants

A questionnaire assessing behavioural determinants using a five-point Likert scale will be administered to all coaches before the intervention. The questionnaire will be developed using an article that describes the assessment of knowledge acquisition, and a manual for developing theory of planned behaviour questionnaires, which assess not only behaviour, but the intention

to perform a behaviour, perceived behavioural control, attitudes towards the behaviour and control beliefs.[63] The construct scores will create “profiles” based on behaviour, habit and intention. Focus groups and a repeated questionnaire will be performed with the intervention coaches after the intervention is completed. The study will assess whether the coaches in the different study groups have different baseline behavioural determinants towards injury prevention programmes. The questionnaires will also determine if there is a change in these determinants of the coaches towards injury prevention in the intervention group coaches after the trial.

Measurement of potential confounders

Despite all study participants being from the same age group, possible confounders include physical/anthropometrical characteristics and maturity status (using body mass, standing height and seated height to predict peak height velocity) which will be collected during the testing.[61] Secondary confounders include injury history, playing experience, playing position and playing level, which will be self-reported. All of the participants will be profiled using those characteristics and therefore these confounders can be considered when analysing the results.

Adherence

This study has been designed to be optimally implemented in community level rugby. The researcher will monitor adherence of the schools using record sheets (hard or electronic copies, depending on the coach preference). These records will then allow for exposure hours to be calculated and a measure of adherence to be determined. The video footage of the warm-up will be collected on a biweekly basis. The video footage of the intervention group’s warm-up will be coded using a five-point Likert scale according to how accurately the exercise routine is performed for every practice.

The study is being performed in the premier league schools where winning is a priority (a decrease in injuries contributes to winning),[52] and therefore the participants in the intervention group will be motivated to implement the injury prevention measures to the best of their abilities.

Analysis

For the injury data, injury rates and corresponding 95% confidence intervals (95% CI) will be calculated for all players as the number of injuries reported per 1000 hours of exposure. The severity of the injuries (missed training/match days) will also be calculated. Further analysis will include the incidence and type of injury (1000 player hours), recurrent versus new injuries

(1000 player hours), contact versus non-contact injuries (1000 player hours), positional injuries (1000 player hours), in what quarter the injury occurred (1000 player hours), injury event (1000 player hours) and the protective gear worn during injury (1000 player hours). Severity will be calculated by the time lost per injury, and injury burden then calculated by days lost per 1000 player hours (mean overall injury incidence multiplied by mean absence per injury). All statistical analyses will be performed using the Stata program (StataCorp LP). A χ^2 test (for categorical variables) and either independent t-tests or Mann-Whitney U tests (for continuous variables) will be performed to determine if the groups are comparable at the beginning of the trial. For the testing data (FMS, EMS and Musculoskeletal Screening Assessment), a “mixed between-within subjects analysis of variance (ANOVA)” to compare the two groups over the whole intervention, and then a *post hoc* Bonferroni test will be used to determine if there is a significant change in the scores and at what time point. If there is a significant change, then at that time point a one-way ANOVA will be performed to determine which specific test is different between groups.[47] A Poisson regression will be used to compare the injury rate differences between the control and intervention group. For the adherence data, descriptive statistics will be used to determine in which areas the program is implemented both the best and the worst. A dose response for each BokSmart *Safe Six* exercise will be ascertained by multiplying the Likert scale (quality of exercise) by adherence over the eighteen weeks. The behavioural determinants data from the questionnaires will be analysed using a Path analysis. The focus groups will be transcribed verbatim, and the common themes grouped using a computer-based thematic analysis. Once this is completed, the barriers and facilitators towards the BokSmart *Safe Six* will be described using frequency analyses.

Project time frame

The following project is being performed over a six-month period during 2017 (April – August).

- January – March 2017: Preparation of data collection material; recruitment of schools; randomisation of schools
- March – April 2017: Baseline testing of players (anthropometrical, FMS, EMS and musculoskeletal); attitudinal surveys of the coaches; training of the coaches
- April – August 2017: Implementation of the exercise intervention; injury surveillance; adherence and exposure data collection; ongoing data entry; video footage of warm-ups analysis
- June 2017: mid-way testing of players (FMS, EMS, musculoskeletal testing)

- September 2017: Final testing of players (FMS, EMS and musculoskeletal); attitudinal surveys and focus groups with the intervention coaches

Outcomes and Significance

Multiple studies have shown that training interventions can have positive effects on injury rates in sports, including rugby.[36, 46] To date, however there are few studies showing effective full-body training intervention programmes within contact sports in real-world contexts. Australia and England have both developed training based interventions for musculoskeletal injuries, and specifically knee injuries.[46, 64] The Australian training programme had low compliance and poor results, however the English study, when adjusted for compliance, was effective in decreasing injury burden, and specifically concussions.[46, 64] General injuries, such as musculoskeletal injuries, may not be as severe as spinal cord injuries, but are costly and can cause problems for players later in life.

This study is the first of its kind in the South African context. This study will also give current data regarding schoolboy rugby injury incidence over a season in South Africa, and will therefore also contribute to the epidemiological knowledge that is currently unknown. Furthermore, the study will provide insight into whether or not the BokSmart *Safe Six* exercises are effective in decreasing injury risk and injury rates.

The attitudinal data will allow for BokSmart to adjust the programme (if necessary) and increase adherence in future.

If the BokSmart *Safe Six* exercises, performed regularly as a warm-up, prove effective in reducing injuries, the benefits will be far reaching for rugby. The exercises have been developed using knowledge of previous effective programmes and international best-practice, and targets the most commonly injured sites in rugby. As the BokSmart *Safe Six* exercises require minimal education and no equipment to implement, the benefits of these exercises will be transferrable to all rugby-playing countries, including the countries with similar socio-economic challenges to those of South Africa.

This project aims to benefit rugby primarily, but all contact sports alike, through proving that a simple, time efficient and cost-effective injury prevention programme, performed during warm-up decreases injury risk and thus makes the game of rugby a safer sport for all.

References

1. Sothorn MS, Loftin M, Suskind RM, Udall JN, Blecker U. The health benefits of physical activity in children and adolescents: implications for chronic disease prevention. *Eur J Pediatr.* 1999;158(4):271-74.
2. Warburton DER, Nicol CW, Bredin SSD. Health benefits of physical activity: the evidence. *Can Med Assoc J.* 2006;174(6):801-09.
3. van Mechelen W, Hlobil H, Kemper HC. Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. *Sports Med.* 1992;14(2):82-99.
4. Mountjoy M, Andersen LB, Armstrong N, et al. International Olympic Committee consensus statement on the health and fitness of young people through physical activity and sport. *Br J Sports Med.* 2011;45(11):839-48.
5. Meir R, Halliday A. Pre- and post-game body mass changes during an international rugby tournament: a practical perspective. *J Strength Cond Res.* 2005:713-16.
6. World Rugby. Year in Review 2016. 2016. Available at: <http://www.worldrugby.org/documents/annual-reports?lang=en>. Accessed 2018 June 7.
7. Duthie G, Pyne D, Hooper S. Applied physiology and game analysis of rugby union. *Sports Med.* 2003:973-91.
8. McLean D. Analysis of the physical demands of international rugby union. *J Sports Sci.* 1992:285-96.
9. Gabbett TJ, Domrow N. Risk Factors for Injury in Subelite Rugby League Players. *Am J Sports Med.* 2005;33(3):428-34.
10. Durandt J, Du Toit S, Borresen J, et al. Fitness and body composition profiling of elite junior South African rugby players. *S Afr J Sports Med.* 2006:38-45.
11. Quarrie K, Wilson B. Force production in the rugby union scrum. *J Sports Sci.* 2000:237-46.
12. Carlson B, Carter J, Patterson P, Petti K, Orfanos S, Noffal G. Physique and motor performance characteristics of US national rugby players. *J Sports Sci.* 1994:403-12.
13. Gabbett T, Jenkins D, Abernethy B. Relationships between physiological, anthropometrical and skill qualities and playing performance in professional rugby league players. *J Sports Sci.* 2011:1655-64.
14. Hendricks S, Lambert M. Tackling in rugby: coaching strategies for effective technique and injury prevention. *Int J Sport Sci and Coach.* 2010:117-31.
15. Quarrie K, Hopkins W. Tackle injuries in professional rugby union. *Am J Sports Med.* 2008:1705-16.
16. Hendricks S, Karpul D, Lambert M. Momentum and kinetic energy during the tackle in rugby union. *J Sports Sci and Med.* 2014;13(3):557-63.
17. Hendricks S, Lambert MI, Brown JC, Readhead C, Viljoen W. An evidence-driven approach to scrum law modifications in amateur rugby played in South Africa. *Br J Sports Med.* 2014;48(14):1115-19.
18. Burger N, Lambert MI, Viljoen W, Brown JC, Readhead C, Hendricks S. Tackle-related injury rates and nature of injuries in South African Youth Week tournament rugby union players (under-13 to under-18): an observational cohort study. *BMJ Open* 2014;4(8).
19. Williams S, Trewartha G, Kemp S, Stokes K. A meta-analysis of injuries in senior men's professional Rugby Union. *Sports Med.* 2013;43(10):1043-55.
20. Hootman JM, Dick R, Agel J. Epidemiology of Collegiate Injuries for 15 Sports: Summary and Recommendations for Injury Prevention Initiatives. *J Athl Train.* 2007;42(2):311-19.

21. Mc Fie S, Brown J, Hendricks S, et al. Incidence and factors associated with concussion injuries at the 2011 to 2014 South African Rugby Union Youth Week tournaments. *Clin J Sport Med.* 2016;26(5):398-404
22. Verhagen EALM, van Mechelen W. Sport for all, injury prevention for all. *Br J Sports Med.* 2010;44(3):158.
23. Brown JC, Viljoen W, Lambert MI, et al. The economic burden of time-loss injuries to youth players participating in week-long rugby union tournaments. *J Sci Med Sport.* 2015;18(4):394-99.
24. Freitag A, Kirkwood G, Pollock AM. Rugby injury surveillance and prevention programmes: are they effective? *BMJ* 2015:350.
25. New Zealand Rugby Union. Technique: the key factors in the tackle and taking the ball into contact. *RugbySmart 2007: A guide to injury prevention for peak performance.* 2007:12-14.
26. Australian Rugby Union. Key points for the tackler and ball-carrier, Australian Rugby Union SmartRugby: Confidence in contact. A guide to the SmartRugby Program. 2008:18-19.
27. SA Rugby. BokSmart: safe and effective techniques in rugby - practical guidelines., 2009.
28. Brown JC, Gardner-Lubbe S, Lambert MI, Van Mechelen W, Verhagen E. The BokSmart intervention programme is associated with improvements in injury prevention behaviours of rugby union players: an ecological cross-sectional study. *Inj Prev.* 2014:injuryprev-2014.
29. Brown JC, Verhagen E, Knol D, Van Mechelen W, Lambert MI. The effectiveness of the nationwide BokSmart rugby injury prevention program on catastrophic injury rates. *Scand J Med Sci Sports.* 2016;26(2):221-25.
30. Quarrie KL, Gianotti SM, Hopkins WG, Hume PA. Effect of nationwide injury prevention programme on serious spinal injuries in New Zealand rugby union: ecological study. *BMJ.* 2007;334(7604):1150.
31. Hendricks S, Jordaan E, Lambert M. Attitude and behaviour of junior rugby union players towards tackling during training and match play. *Safety Sci.* 2012:266-84.
32. Hendricks S, Karpul D, Nicolls F, Lambert M. Velocity and acceleration before contact in the tackle during rugby union matches. *J Sport Sci.* 2012:1215-24.
33. Hendricks S, Matthews B, Roode B, Lambert M. Tackler characteristics associated with tackle performance in rugby union. *Eur J Sport Sci.* 2014:1-10.
34. Gabbett TJ, Ullah S, Finch CF. Identifying risk factors for contact injury in professional rugby league players--application of a frailty model for recurrent injury. *J Sci Med Sport* 2012;15(6):496-504.
35. Verrall GM, Slavotinek JP, Barnes PG. The effect of sports specific training on reducing the incidence of hamstring injuries in professional Australian Rules football players. *Br J Sports Med.* 2005;39(6):363-68.
36. Brooks JH, Fuller CW, Kemp SP, Reddin DB. Incidence, risk, and prevention of hamstring muscle injuries in professional rugby union. *Am J Sports Med.* 2006;34(8):1297-306.
37. Gabbe BJ, Branson R, Bennell KL. A pilot randomised controlled trial of eccentric exercise to prevent hamstring injuries in community-level Australian Football. *J Sci Med Sport.* 2006;9(1-2):103-9.
38. McHugh MP, Tyler TF, Mirabella MR, Mullaney MJ, Nicholas SJ. The effectiveness of a balance training intervention in reducing the incidence of noncontact ankle sprains in high school Football players. *Am J Sports Med.* 2007;35(8):1289-94.
39. Deydre S, Teyhen, Shaffer SW, Lorensen CL, et al. The Functional Movement Screen: A reliability study. *J Orthop Sports Phys Ther.* 2012;42(6):530-40.

40. Kraus K, Schutz E, Taylor W, Doyscher R. Efficacy of the Functional Movement Screen: a review. *J Strength Cond Res.* 2014;28(12):14.
41. Kiesel K, Plisky P, Butler R. Functional movement test scores improve following a standardized off-season intervention program in professional football players. *Scand J Med Sci Sports* 2011;21(2):287-92.
42. Bodden JG, Needham Ra Fau - Chockalingam N, Chockalingam N. The effect of an intervention program on functional movement screen test scores in mixed martial arts athletes. 2015;29(1):219-25.
43. Gabbe BJ, Finch CF, Bennell KL, Wajswelner H. Risk factors for hamstring injuries in community level Australian football. *Br J Sports Med.* 2005;39(2):106-10.
44. Gabbe BJ, Bennell KL, Finch CF, Wajswelner H, Orchard JW. Predictors of hamstring injury at the elite level of Australian football. *Scand. J Med Sci Sports* 2006;16:7.
45. Altman DG, Schulz KF, Moher D, et al. The Revised CONSORT Statement for Reporting Randomized Trials: Explanation and Elaboration. *Ann Intern Med.* 2001;134(8):663-94.
46. Finch CF, Twomey DM, Fortington LV, et al. Preventing Australian football injuries with a targeted neuromuscular control exercise programme: comparative injury rates from a training intervention delivered in a clustered randomised controlled trial. *Inj Prev.* 2015 doi: 10.1136/injuryprev-2015.
47. Fuller C, Molloy M, Bagate C, et al. Concensus statement on injury definitions and data collection procedures for studies of injuries in rugby union. *Br J Sports Med.* 2007:328-31.
48. Cook DJ, Cusimano MD, Tator CH, Chipman ML. Evaluation of the ThinkFirst Canada, Smart Hockey, brain and spinal cord injury prevention video. *Inj Prev.* 2003;9(4):361-66.
49. Fortington LV, Donaldson A, Lathlean T, et al. When 'just doing it' is not enough: Assessing the fidelity of player performance of an injury prevention exercise program. *J Sci Med Sport* 2015;18(3):272-77.
50. Wong LP. Focus group discussion: a tool for health and medical research. *Singapore Med J.* 2008;49(3):256-60
51. Readhead C, Viljoen W, Suter J. Safety in the playing environment document, BokSmart. 2015.
52. Williams S, Trewartha G, Kemp SPT, et al. Time loss injuries compromise team success in Elite Rugby Union: a 7-year prospective study. *Br J Sports Med.* 2015:doi: 10.1136/bjsports-2015-094798.
53. Cook G, Burton L, Hoogenboom B. Pre-Participation Screening: The Use of Fundamental Movements as an Assessment of Function – Part 1. *N Am J Sports Phys Ther : NAJSPT* 2006;1(2):62-72.
54. Cook G, Burton L, Hoogenboom B. Pre-Participation Screening: The Use of Fundamental Movements as an Assessment of Function – Part 2. *N Am J Sports Phys Ther: NAJSPT* 2006;1(3):132-39.
55. Cools AM, De Wilde L, Van Tongel A, Ceysens C, Ryckewaert R, Cambier DC. Measuring shoulder external and internal rotation strength and range of motion: comprehensive intra-rater and inter-rater reliability study of several testing protocols. *J Shoulder Elbow Surg.* 2014;23(10):1454-61.
56. Dennis RJ, Finch CF, Elliott BC, Farhart PJ. The reliability of musculoskeletal screening tests used in cricket. *Phys Ther Sport* 2008;9(1):25-33.
57. Gabbe BJ, Bennell KL, Wajswelner H, Finch CF. Reliability of common lower extremity musculoskeletal screening tests. *Phys Ther Sport* 2004;5(2):90-97.
58. Brukner P, Khan KM. Low back pain. In: *Clinical Sports Medicine.* McGraw Hill Companies Inc. 2001(2nd eds.):330-59.

59. Lin J-j, Yang J-L. Reliability and validity of shoulder tightness measurement in patients with stiff shoulders. *Man Ther.* 2006;11(2):146-52.
60. Eechaute C, Vaes P, Duquet W. Functional Performance Deficits in Patients With CAI: Validity of the Multiple Hop Test. *Clin J Sport Med.* 2008;18(2):124-29.
61. Mirwald RL, Baxter-Jones AD, Bailey DA, Beunen GP. An assessment of maturity from anthropometric measurements. *Med Sci Sports Exer.* 2002;34(4):689-94.
62. Durnin J, Womersley J. Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged 16 to 72 years. *Br J Nutr.* 1974;77-97.
63. Francis JJ, Eccles MP, Johnston M, et al. Constructing questionnaires based on the theory of planned behaviour. *A manual for health services researchers* 2004;2010:2-12.
64. Hislop MD, Stokes KA, Williams S, et al. The efficacy of a movement control exercise programme to reduce injuries in youth rugby: a cluster randomised controlled trial. *BMJ Open Sport & Exer Med.* 2016;2(1).

CHAPTER 7:

SEASONAL MATCH INJURY RATES AND BURDEN IN THREE SOUTH AFRICAN UNDER-16 SCHOOLBOY TEAMS

Submitted

Abstract

Background

Youth rugby union is a popular sport with a high injury incidence density (IID) and burden. This high risk has called for further research into the factors affecting the injuries in youth rugby. The aim of the study was to analyse time-loss IID and burden in multiple schoolboy rugby teams over a season and the potential factors associated with injury.

Methods

All time-loss injuries were recorded from three schools including 130 players for the whole 2017 season. Overall IID and injury burden were calculated, as well as for injury event, type, location and the match quarter in which they occurred, and Poisson regression analyses were performed to determine differences.

Results

IID was 28.8 (18.9 – 38.6) injuries per 1000 player hours over the season, with an injury burden of 379.2 (343.6 – 414.9) days lost per 1000 player hours. The ball-carrier had a significantly higher IID (11.3 (5.2 – 17.5) per 1000 player hours) compared to other events, and the joint (non-bone)/ligament injuries were the most common (IID of 12.2 (5.8 – 18.6) per 1000 player hours) and had the greatest burden (172.6 (148.5 – 196.6) days lost per 1000 player hours). The lower limb had the highest injury incidence (13.9 (7.1 – 20.8) per 1000 player hours).

Conclusion

The IID was similar to previous youth rugby studies. However, the injury burden was much lower. The South African youth cohort showed similar factors associated with injury for inciting event (the tackle) and injury type (joint (non-bone)/ligament) and location (lower limb) as seen in other studies in both youth and senior players.

Introduction

Physical activity has numerous benefits, such as decreasing chronic disease risks, improving body composition (e.g. decrease in fat percentage and increase in lean muscle mass) and increasing physical fitness (e.g. aerobic capacity).[1, 2] Although increases in participation in physical activity have numerous physical, social and emotional benefits,[2] formalised sport, has an additional complication of concurrent increases in sports-related injuries. This adds a new dimension to consider when weighing up the risks versus benefits of participation.[3]

Rugby union (hence referred to as ‘rugby’) is a form of organised physical activity and has become a popular sport worldwide, with approximately 468 000 players in South Africa.[4] With an injury incidence density (IID) of 81 (95% CI 63 – 105) injuries per 1000 match hours in senior players,[5] 35 injuries per 1000 match hours (95% CI 29 – 41) in English youth competitions,[6] and 22 injuries per 1000 player hours (95% CI 20 – 25) reported in South African youth tournaments,[7] rugby is associated with higher injury rates than many other sports.[8] Whilst South African youth tournament injury rates and injury burden have been thoroughly investigated,[7, 9-14] minimal research is available for South African youth rugby teams over a season, which would represent a more accurate reflection of rugby played at school level. A study has investigated a single youth rugby team in South Africa over one season and found an alarmingly high IID and injury burden for this team.[15]

Therefore, a more comprehensive, multiple team and multiple school prospective study is needed to determine a more accurate representation of IID and injury burden in this population, in order to take appropriate efforts to reduce injury burden.

Furthermore, under-16 rugby players are thought to be a vulnerable group, as the disparity in size and ability within this age group is larger, with players ranging from pre-pubescent, pubescent to post-pubescent, compared to older cohorts where maturation would be achieved.[16] This disparity in development could lead to an increased injury risk, and therefore the injury profiles of under-16 youth players need to be explored further.

Multiple factors are related to the aetiology of rugby injuries and have been investigated in both the youth and in seniors.[5, 6, 17-19] The tackle event has the highest injury incidence and the lower limb was the site most commonly injured.[5, 19] However, in the South African youth cohort further insight into variables that describe the nature of these rugby injuries over a season need to be assessed. Better understanding the real injury burden and aetiology of

injuries in South African youth rugby, will contribute to the development of effective injury prevention programmes or the refinement of existing programmes for this population.

Therefore, the primary aim of this study was to determine the time-loss match IID and injury burden of under-16 schoolboy rugby players in South Africa. A secondary aim was to investigate potential factors related to injury incidence density and injury burden in these players.

Methods

Out of twelve eligible Western Cape schools, a convenience sample of four coaches of four schools were asked to invite their players to participate in the study. One school declined to participate in the study. All players and their parents/guardians who were willing to participate signed written informed consent. Players were able to withdraw at any point during the study. The Western Cape Education Department and the UCT Human Research Ethics Committee (HREC 850/2015) granted ethical clearance. This study is part of a larger study.[20]

Injury data collection was performed at the remaining three schools from the Western Cape region. All of these three schools were of a high level, participating in the premier league. The season consisted of approximately sixteen matches for each school, with the season extending from April to August 2017. The players included in the study were from under-16 teams. Each school recorded the injuries sustained by their players and the teams were contacted on a Monday to send in the injury reports. The injuries were recorded using an injury data collection form designed by SA Rugby in accordance with the injury surveillance Consensus Statement [21] and which has been used in previous studies (Appendix II).[9, 12] A medical professional confirmed all reported injuries. Only match time-loss injuries (an injury occurring during a match which resulted in a player being absent for more than 24 hours of normal activity)[21] were recorded for this study. All injuries were followed up until the player returned to sport to determine an accurate injury severity (minimal 2-3 days; mild 4-7 days; moderate 8-28 days; severe >28 days missed) and injury burden. Associated risk factors were also recorded: injury event (tackle (additionally separated into tackler and ball carrier roles), ruck, open play, running, lineout, scrum, maul, kicking); injury type (joint (non-bone)/ligament; central/peripheral nervous system; broken bone/fracture; muscle/tendon; bruise/contusion; laceration; other injury (unsure)); game quarter (first, second, third or fourth), and; injury location (head/neck, trunk, upper limb, lower limb). The definitions of each of these factors were in accordance with the injury surveillance Consensus Statement.[21]

Player match exposure was calculated, according to the current Consensus Statement:[21]

$$Exposure = NM \times PM \times DM$$

For this equation, *NM* is the number of matches played, *PM* is the number of players per match, (always 15 players, the number of players on the pitch for one team at any given time), and *DM* is the match duration in hours. Exposure was used to determine the IID per 1000 player match hours and the corresponding 95% Confidence Intervals (95% CI).

Injury burden was calculated using the following equation:[21]

$$Injury\ Burden = overall\ mean\ injury\ incidence\ density \times mean\ absence\ per\ injury$$

Injury burden is expressed as the number of injury days lost per 1000 player hours and 95% CI. Poisson regression analysis using IBM SPSS Statistics 24 (2016) was performed to determine if there were significant differences between the associated injury risk factors (phases of play, injury types, game quarters and injury locations).

Results

In the 2017 season, there were 33 time-loss match injuries over 1147 exposure hours in total, comprising three schools and six different teams (130 different players, no players declined participation). The overall IID for the season was 28.8 (18.9 – 38.6) injuries per 1000 player hours.

Of the 33 time-loss injuries, 36% were of “minimal” severity (2 – 3 days missed), however, 12% were “severe” (>28 days missed), and mean severity was 12 days. Overall, the injury burden for the season was 379.2 (343.6 – 414.9) days lost per 1000 player hours.

The tackle phase of play was broken down into tackler and ball-carrier roles. The ball-carrier had the highest IID of all events, 11.3 (5.2 – 17.5) per 1000 player hours, with the tackler role (7 (2.1 – 11.8) per 1000 player hours) and ruck (4.4 (0.5 – 8.2) injuries per 1000 player hours) having the next highest IID, respectively. All events, excepting the tackler role and ruck, were significantly lower than the ball-carrier (Figure 7.1). The injury burden of the ball-carrier was 158.4 (135.4 – 181.4) days lost per 1000 player hours, and the injury burden for the tackler was 32.0 (21.7 – 42.4) days lost per 1000 player hours.

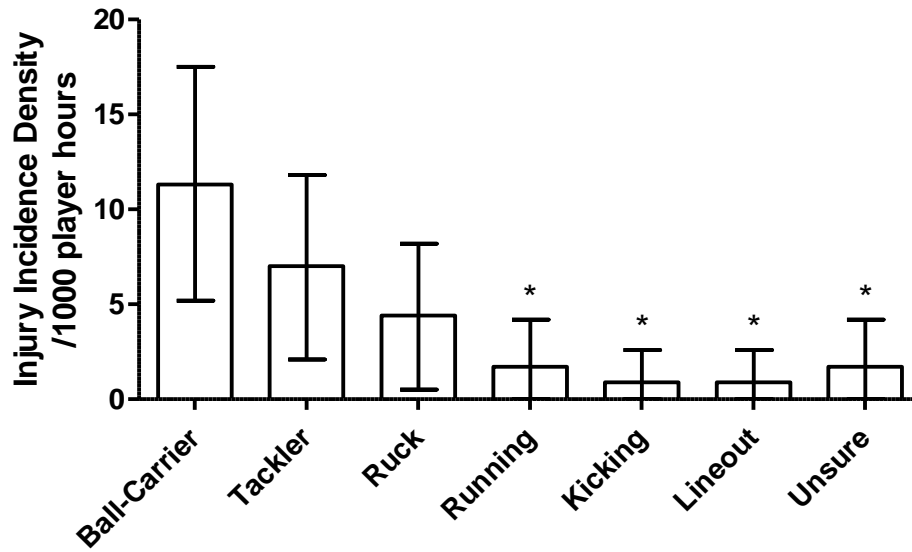


Figure 7.1: IID for injury events during the season. (*significantly different to Ball-Carrier; $p < 0.05$).

Joint (non-bone)/ligament injuries were the most common and severe, with an IID of 12.2 (5.8 – 18.6) injuries per 1000 player hours and a burden of 172.6 (148.5 – 196.6) days lost per 1000 player hours. The second most common injury type was that of central/peripheral nervous system (CNS/PNS) injuries with an IID of 6.1 (1.6 – 10.6) injuries per 1000 player hours, with a burden of 120.0 (99.9 – 140.0) days lost per 1000 player hours (Figure 7.2). It must be noted that all of the CNS/PNS injuries in this cohort were concussions.

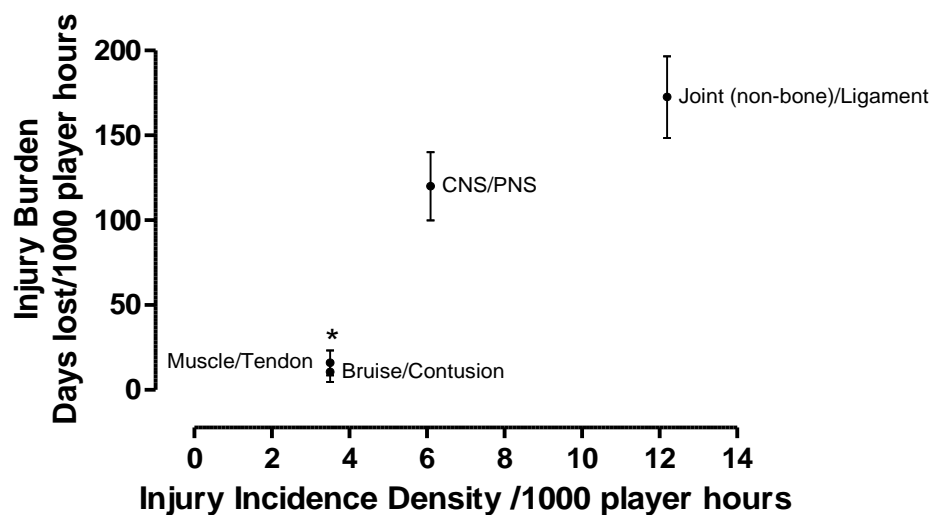


Figure 7.2: IID and burden for injury type during the season. (*both Muscle/Tendon and Bruise/Contusion were significantly different to Joint (non-bone)/Ligament injuries; $p < 0.05$).

Table 7.1: Specific injury location.

Injury Location	%
Ankle	27
Front of thigh	6
Hand/Finger/Thumb	9
Head/ Face	21
Hip/Groin	3
Knee	12
Neck/Cervical	3
Shoulder/Collar Bone	18

The body location with the highest IID was the lower limb: (13.9 (7.1 – 20.8) injuries per 1000 player hours), followed by the upper limb (7.8 (2.7 – 13.0) injuries per 1000 player hours) and then head/neck region (7.0 (2.1 – 11.8) injuries per 1000 player hours). The lower limb injuries also had the highest burden of 164.7 (141.3 – 188.2) days lost per 1000 player hours, whilst the head/neck injuries had a higher injury burden than the upper limb, with a burden of 122.8 (102.5 – 143.0) days lost per 1000 player hours (Figure 7.3).

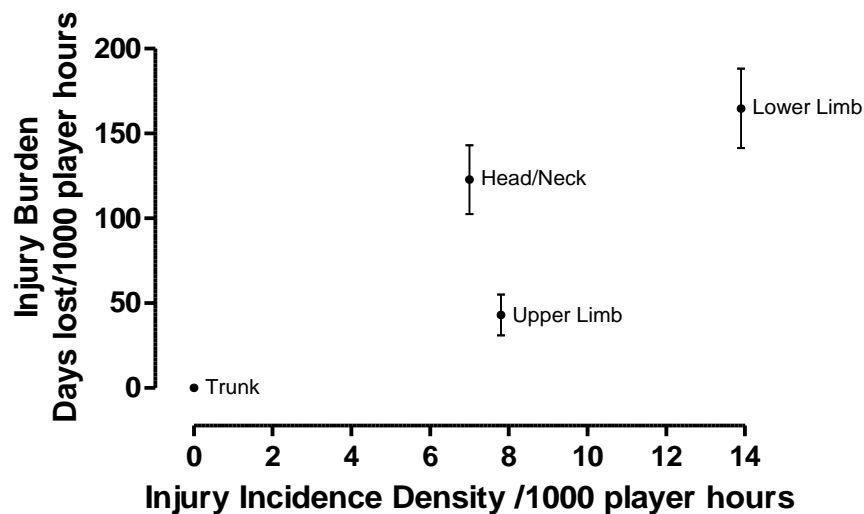


Figure 7.3: IID and burden for injury location during the season.

Most injuries occurred in the first quarter of the match, followed by the fourth and then the third quarter. The first quarter had an IID of 10.5 (4.5 – 16.4) injuries per 1000 player hours. The second quarter had a significantly lower IID (2.6 (0.0 – 5.6) injuries per 1000 player hours) compared to the first quarter.

Discussion

The aim of this study was to determine the time-loss match IID and injury burden of under-16 schoolboy rugby players in South Africa. The match IID for a season was 28.8 (18.9 – 38.6) per 1000 player hours for under-16 youth rugby players from the three different schools. This IID is comparable to the ranges of previous European youth rugby seasonal studies, where the reported IID were between 24 – 35 injuries per 1000 player hours.[6, 17, 19, 22] These results would indicate that the youth community rugby population of South Africa has an IID comparable to European cohorts when comparing overall injury incidences. These European cohorts were slightly older compared to the under-16 players included in this South African season-long study, and the support received at the European schools and the European competitions is unknown; this could play a role in the injury rates reported. Moreover, these results are comparable to that of a similarly aged South African youth tournament population.[7] However, when the injury data are compared further, the injury burden does not follow a trend comparable to that of the European cohorts. The injury burden for the present study was 379 days lost per 1000 player hours, which is much less than the reported injury burden from Hislop *et al.* (2017) (observed in the control group of their trial), where the injury burden was 862 days lost per 1000 player hours.[22] Another study conducted in Europe,[6] reported that tackling alone was responsible for an injury burden of 264 days lost per 1000 player hours, compared to 32 days lost per 1000 player hours in our current South African cohort illustrating a large discrepancy. In another study performed in youth rugby, 49% of injuries was classified as severe (>28 days lost), compared to 12% reported in our study, indicating a disparity in the severity of injuries between the cohorts.[17] This injury severity is much lower than previous European studies, and could, therefore, indicate that whilst the injury incidences are similar, the South African youth population has less severe injuries.

When examining the literature, the injury type and location of injuries vary among age groups, depending on how recent the data are. The most commonly occurring injuries in this study were joint (non-bone)/ligament and CNS/PNS injuries. In the present study, the lower limb had the highest injury incidence, as was to be expected with a high rate of joint (non-bone)/ligament injuries. However, this was not significantly different to the upper limb and the head/neck areas. The lower limb injury incidence (13.9 injuries per 1000 player hours) was much higher than previous studies, both recent and older studies, where the incidence was reported between 7 and 8 injuries per 1000 player hours.[19, 22] Joint (non-bone)/ligament injuries had an

incidence of 12.2 injuries per 1000 player hours, which is similar to that reported by another schoolboy study with an incidence of 14 injuries per 1000 player hours (also the largest contributor to injuries).[6] When comparing the types of injuries, in more recent literature, CNS/PNS injuries have been shown to have a higher incidence than previously reported. This could be due to an increased awareness of concussions (through national and international rugby unions),[23] including the reporting of both confirmed and suspected concussions.[22] The concussion incidence in this study was 6.1 injuries per 1000 player hours, compared to older studies with an incidence of 1.8 injuries per 1000 player hours during a season.[19] However, in more recent studies, an IID of 6 injuries per 1000 player hours during a season,[22] and 9.1 injuries per 1000 player hours during tournaments were found.[7] Another study showed a CNS/PNS incidence of 3 injuries per 1000 player hours, again much lower than presented in this study.[6] Whilst older youth literature indicates joint (non-bone)/ligament injuries are common and of similar incidence rates to what was found in this South African cohort, the CNS/PNS incidence reported in this cohort was still much higher than that reported in the older seasonal studies.[6, 19] The youth population should be carefully monitored regarding those data, especially as concussion is an ever developing epidemiological field and the long-term effects are still relatively unknown.

Similar to previous research, the most injury inciting event in this South African youth cohort was the tackle event.[5, 6, 9, 12, 18, 19] The ball-carrier role had the highest injury incidence in this study, but this was not significantly different to the tackler. This is in agreement with previous studies for both youth and professional rugby where the data has been divided into the two roles and where the ball-carrier is at greater risk of injury. There are also studies indicating the opposite.[5, 6, 24-26] However, the statistical differences between these two roles are rarely significant and most studies report and compare IID data by combining the roles and look at the tackle as a whole. For injury prevention purposes, however, it is important to look at the tackler and ball-carrier roles separately, as the mechanisms of injury are different. Comparable with other studies, after the tackle event, the ruck was the next highest contributor to injuries.[5, 19] IID per injury event. However, the ruck is a raw measure of the mechanisms of injury, as it does not account for how often the events occur in a match, compared to the number of injuries. For example, there are fewer lineouts, scrums and rucks occurring in a match compared to tackles,[27] and therefore one would expect there to be more injuries occurring as a result of tackles, simply because more match time is spent on tackling than on the other phases. These higher injury rates in the tackle compared to the other phases of play

have resulted in injury prevention programmes focusing on this area. Multiple studies have now shown that safe and effective technique in the tackle can potentially reduce injury rates in the tackle situation.[11, 14, 28]

The timing of injuries was highest in the first quarter, slightly lower in the third and fourth quarter, but significantly lower in the second quarter. Having a high IID in the third and fourth quarter is common in studies on both youth and professional rugby;[5, 7] however, these studies have shown a significantly lower incidence in the first quarter compared to all other quarters, contrary to this South African cohort.[5, 18, 29] Possible explanations for the increases seen in IID in the third and fourth quarters are the lull in concentration in the third quarter (from the half-time break), and the fatigue factor.[5, 18, 29] However, the reason for the highest injury rates in the first quarter has yet to be explained.[18] This increase in injury in the first quarter could be attributed to a lack of preparatory conditioning as all of the first quarter injuries occurred in the first half of the season. Another explanation was the over-exuberance of players at the start of the match to establish physical dominance early in a match.

The limitations of this study were that this was a single season prospective cohort study of a single age group carried out in a convenience sample of subjects. Therefore, interpretations should be made with caution beyond this convenience sample and age group. Also, injury incidence studies do not account for the time spent performing a specific activity in a sport, and therefore do not adjust for commonly occurring events compared to rare events.

Conclusion

This under-16 South African youth rugby cohort had an average match injury incidence of 28 injuries per 1000 player hours for one season. Although this IID is comparable to that of other youth cohorts, the injury burden was much lower at 379 days per 1000 player hours. This discrepancy was a result of the average injury being less severe in the present study. The tackle again was shown to be the main injury-causing event, with this study showing the ball carrier to be more frequently injured than the tackler. The risk factors associated with injury were comparable to those in European youth rugby, with joint (non-bone)/ligament injuries having the highest injury incidence. The incidence of CNS/PNS injuries, of which concussion was the majority contributor, is still worthy of further monitoring. A larger cohort is needed to further investigate the match period in which the injuries are occurring as this cohort showed interesting information into the timing of injuries in South African youth rugby. South African

youth rugby has been under-researched in a seasonal context, and this provides further insight into the characteristics of the injuries occurring at this level.

References

1. Sothorn MS, Loftin M, Suskind RM, et al. The health benefits of physical activity in children and adolescents: implications for chronic disease prevention. *Eur J Pediatr.* 1999;158(4):271-74.
2. Warburton DER, Nicol CW, Bredin SSD. Health benefits of physical activity: the evidence. *Can Med Assoc J.* 2006;174(6):801-09.
3. van Mechelen W, Hlobil H, Kemper HC. Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. *Sports Med.* 1992;14(2):82-99.
4. World Rugby. Year in Review 2016. 2016. Available at: <http://www.worldrugby.org/documents/annual-reports?lang=en>. Accessed 2018 June 07.
5. Williams S, Trewartha G, Kemp S, et al. A meta-analysis of injuries in senior men's professional Rugby Union. *Sports Med.* 2013;43(10):1043-55.
6. Palmer-Green DS, Stokes KA, Fuller CW, et al. Match injuries in English youth academy and schools Rugby Union: an epidemiological study. *Am J Sports Med.* 2013;41(4):749-55.
7. Mc Fie S, Brown J, Hendricks S, et al. Incidence and Factors Associated With Concussion Injuries at the 2011 to 2014 South African Rugby Union Youth Week Tournaments. *Clin J Sport Med.* 2016;26(5):398-404.
8. Hootman JM, Dick R, Agel J. Epidemiology of Collegiate injuries for 15 Sports: summary and recommendations for injury prevention initiatives. *J Athl Train.* 2007;42(2):311-19.
9. Brown J, Verhagen E, Viljoen W, et al. The incidence and severity of injuries at the 2011 South African Rugby Union (SARU) Youth Week tournaments. *S Afr J Sports Med.* 2012:49-54.
10. Brown JC, Viljoen W, Lambert MI, et al. The economic burden of time-loss injuries to youth players participating in week-long rugby union tournaments. *J Sci Med Sport.* 2015;18(4):394-99.
11. Burger N, Lambert MI, Viljoen W, et al. Mechanisms and factors associated with tackle-related injuries in South African Youth Rugby Union players. *Am J Sports Med.* 2017;45(2):278-85.
12. Burger N, Lambert MI, Viljoen W, et al. Tackle-related injury rates and nature of injuries in South African Youth Week tournament rugby union players (under-13 to under-18): an observational cohort study. *BMJ Open.* 2014;4(8).
13. Burger N, Lambert MI, Viljoen W, et al. Tackle technique and tackle-related injuries in high-level South African Rugby Union under-18 players: real-match video analysis. *Br J Sports Med.* 2016;50(15):932-38.
14. Hendricks S, O'connor S, Lambert M, et al. Contact technique and concussions in the South African under-18 Coca-Cola Craven Week Rugby tournament. *Eur J Sport Sci.* 2015;15(6):557-64.
15. Tee JC, Lebatie F, Till K, et al. Injury incidence and characteristics in South African school first team rugby: a case study. *S Afr J Sport Med.* 2017;29:1-7.
16. Durandt J, Du Toit S, Borresen J, et al. Fitness and body composition profiling of elite junior South African rugby players. *S Afr J Sports Med.* 2006;18(2):38-45.
17. Archbold HAP, Rankin AT, Webb M, et al. RISUS study: Rugby Injury Surveillance in Ulster Schools. *Br J Sports Med.* 2017;51(7):600-06.
18. Brooks J, Fuller C, Kemp S, et al. Epidemiology of injuries in English professional rugby union: part 1 match injuries: *Br J of Sports Med.* 2005:757-66.
19. Haseler CM, Carmont MR, England M. The epidemiology of injuries in English youth community rugby union. *Br J Sports Med.* 2010;44(15):1093-99.

20. Sewry N, Verhagen E, Lambert M, et al. Evaluation of the Effectiveness and Implementation of the BokSmart Safe Six Injury Prevention Programme: a study protocol. *Inj Prev.* 2017;23:428.
21. Fuller C, Molloy M, Bagate C, et al. Consensus statement on injury definitions and data collection procedures for studies of injuries in rugby union. *Br J Sports Med.* 2007;328-31.
22. Hislop MD, Stokes KA, Williams S, et al. Reducing musculoskeletal injury and concussion risk in schoolboy rugby players with a pre-activity movement control exercise programme: a cluster randomised controlled trial. *Br J Sports Med.* 2017;51:1140-46.
23. Viljoen W, Patricios J. BokSmart – implementing a National Rugby Safety Programme. *Br J Sports Med.* 2012;46(10):692-93.
24. Fuller C, Molloy M. Epidemiological study of injuries in men's international under-20 rugby union tournaments. *Clin J Sports Med.* 2011:356-58.
25. Fuller CW, Laborde F, Leather RJ, et al. International Rugby Board Rugby World Cup 2007 injury surveillance study. *Br J Sports Med.* 2008;42(6):452-59.
26. Fuller CW, Sheerin K, Targett S. Rugby World Cup 2011: International Rugby Board Injury Surveillance Study. *Br J Sports Med.* 2013;47(18):1184-91.
27. Duthie G, Pyne D, Hooper S. Applied physiology and game analysis of rugby union. *Sports Med.* 2003:973-91.
28. Hendricks S, Lambert M. Tackling in rugby: coaching strategies for effective technique and injury prevention. *Int J Sports Sci and Coach.* 2010:117-31.
29. Bathgate A, Best J, Craig G, et al. A prospective study of injuries to elite Australian rugby union players. *Br J Sports Med.* 2002:265-69.

CHAPTER 8:

EFFECTIVENESS OF THE BOKSMART *SAFE SIX* EXERCISE PROGRAMME ON INJURY RATES AND INJURY RISK PROFILES OF UNDER-16 MALE RUGBY PLAYERS

Abstract

Background

Exercise-based interventions have proven effective in many sports to reduce injury risk. The BokSmart *Safe Six* is a preventive warm-up programme developed for youth rugby, consisting of six exercises targeted to decrease injury risk. The aim of this study was to determine the effectiveness of the BokSmart *Safe Six* programme on improving injury risk profiles.

Methods

A cluster-randomised controlled trial was performed during the 2017 rugby season in the Western Cape, South Africa. A total of 6 Schools participated (3 in the intervention and 3 in the control group), consisting of 210 rugby players between the ages of 15 and 16 years. Intervention schools were instructed to perform the *Safe Six* exercises at least three times a week during the entire season. Changes in Functional Movement Screen (FMS) scores and the BokSmart Musculoskeletal Screening Assessment scores were assessed as mediators of injury risk, at three time points; 0 weeks (pre-intervention), 9 weeks (mid-intervention) and 18 weeks (post-intervention). Match time-loss injury incidence density was recorded during the season.

Results

There was a significant change in two of the BokSmart Musculoskeletal Screening Assessment scores: improvement in lumbar flexion score and decrease in range of motion of the hip (Thomas hip score); however, no changes in the overall FMS score were found. No differences in injury incidence densities between groups were found.

Conclusions

The BokSmart *Safe Six* showed minimal changes in the BokSmart Musculoskeletal Screening Assessment and no changes in the FMS scores over the season (18 weeks), and BokSmart should investigate adjusting the programme with additions from other effective rugby interventions.

Introduction

Youth rugby has a high risk of injury compared to other sports.[1-3] The popularity of the sport[4] and this high injury risk has led to the need for the effective implementation of injury prevention strategies. The nature of the injuries sustained in rugby (specifically concussions and contact-related injuries) has made it difficult to design effective injury prevention programmes.[2, 3, 5-7] However, four underpowered studies with a low level of evidence have shown hamstring exercises,[8] neck strengthening exercises,[9] proprioceptive training[10] and progressive training to be effective in reducing injuries in contact sports.[11] Furthermore, a sufficiently powered, cluster-randomised controlled trial (cRCT) in England showed reduced concussion rates in youth and senior rugby players, who had followed an exercise-based injury prevention programme.[12, 13] Although this specific intervention required intensive coach training and training programme progressions throughout the season, it indicated that exercise-based injury prevention programmes can be effective in rugby.[12]

In accordance, BokSmart, together with the South African Rugby Union (SARU), developed and implemented the BokSmart *Safe Six* exercise-based injury prevention programme in 2014. The *Safe Six* programme was designed to be incorporated in the regular warm-up before training and matches, requiring no equipment and minimal training. Awareness about this programme has grown since its launch.[14, 15] The simplicity of the *Safe Six* (takes six minutes to perform, no progressions) makes it different to the programme used in the above-mentioned RCT performed in England (multiple progressions and takes approximately 20 minutes to perform),[12, 13] and makes it more applicable to the disparate socio-economic conditions in South Africa. The *Safe Six* exercises were chosen based on clinical practice and previous research, and target the commonly injured sites in rugby.[5, 7, 16] Exercise-based interventions (such as the *Safe Six*) in collision sports are hypothesised to assist in improving motor control patterns, that potentially result in a decrease in contact and non-contact injuries sustained.[17] Previous studies have established the association between motor control measures and injury, where motor control outcomes are mediating injury risk and can thus be seen as a proxy for injury.[18-21] Assessment of motor control scores, as mediators of injury risk, can serve to establish injury risk profiles.[18-20] Examples of a tool to assess motor control scores include the Functional Movement Screen (FMS) and other range of motion measurements.[22-28]

The aim of this study was to determine the effectiveness of the BokSmart *Safe Six* exercises on improving injury risk profile scores. The secondary aim is to determine the effectiveness of the BokSmart *Safe Six* on reducing injury rates in under-16 rugby union players. The hypothesis is that the BokSmart *Safe Six* programme will be associated with improvements in injury risk profile scores and with decreases in injury incidence density.

Methods

Design & recruitment

All eight secondary schools from the Western Province Rugby Union's School Premier League or Division (based on location and similar skill level) were approached to participate in this study. Despite being in the same league, the eight schools are geographically separated by at least 40 km: four schools were in the Stellenbosch/Paarl region and four were in the Southern Suburbs region. A 'coin-flip' was used to randomise the intervention and control schools, based on geographic region. This coin-flip decided that the Southern Suburbs schools would receive the *Safe Six* intervention. All schools were approached through their headmaster, head of sport, head of rugby and head under-16 rugby coach to participate in the study. Two of the eight schools (one from the control and one from the intervention group) declined to participate, as the one team was travelling overseas and the other team was already trialling another intervention, leaving six participating schools (three in each arm). The school's medical resources on match day were standardised by BokSmart protocols.[29] All schools were required to have access to at least a physiotherapist for their players when necessary, and therefore in the case of injuries, a diagnosis was available. Once the school had agreed to participate, written assent from players and written consent from parent/guardian and the coach of those willing to participate were obtained before the study began.

The UCT Human Research Ethics Committee granted Ethical approval (HREC 850/2015) and the study was performed in accordance with the Consolidated Standards of Reporting Trials Statement and was registered prospectively (trial number: PACTR201608001730223).

Sample size

The sample size was calculated before the start of the study[14, 30] to be able to detect a 30% improvement in FMS scores at the 95% confidence level, with a clustering effect, requiring 4 schools in each arm (hence the recruitment numbers). However, the school random effect

(clustering effect) did not add to the mixed model and therefore the clustering effect was not necessary. Using an individualized randomized controlled trial design, the sample size required was 8 participants in the intervention group and 8 in the control group to see a 30% improvement in FMS scores, assuming a standard deviation of 3.0 and 2.0 for the control group and the intervention group, respectively.[30] The study was not statistically powered to detect changes in injury incidence densities.

Intervention

The schools allocated to the intervention group were instructed to perform the BokSmart *Safe Six* exercises three times a week during their warm-up at practice (the schools could choose whether they wanted to add more exercises into their warm-up). The coaches were trained to administer the exercises. Training included one-on-one training and YouTube videos and posters about the intervention. All six exercises took approximately six minutes to complete and included shuttle runs, multi-directional lunges, Nordic hamstring curls, push-up with rotation, lunges with a knee lift and dynamic reaches.[14] The researcher (NS) visited the schools every two weeks to retrieve video footage of both the control and intervention schools' warm-ups in an attempt to improve compliance of the intervention group. This material was used also for accountability reasons.

Blinding was not possible in this study, as the control group was not given an intervention. However, this was overcome to some extent by not informing either group that another group was performing something different. The control group was instructed that the study was investigating warm-ups performed by schools and their preventive effects. It must be noted that there was no specific instruction to the control group to not perform the *Safe Six* exercises (as it is a freely available programme).

Outcome Measures and Data Collection

Each school was tested three times during the study to determine the players' level of motor control and functional movement. The testing battery included: 7 FMS exercises (leading to individual test scores [scale 0 – 3] and to a composite score [range 0 – 21]),[23, 24] and eight range of motion tests from the BokSmart Musculoskeletal Screening Assessment (active knee extension [°], modified Thomas test [°], active internal and external range of motion of the hip [°], ankle dorsiflexion lunge [cm], sit and reach [cm], lumbar spine extension [cm] and forward flexion [cm], shoulder internal and external rotation [°]).[22, 26-28, 31] Anthropometrical (sum of four skinfolds, body height and body mass) and maturation status (derived from seated

height and standing body height to determine years after peak height velocity) were measured also as these factors might confound results.[32, 33] All tests were performed once at three time points (before the teams' first match, before the mid-season break and after their final match) by biokineticists/physiotherapists/sports scientists specifically trained for the study. The testers were blinded to the group allocation (control/intervention) of each school.

Match time-loss injury data were recorded by the coach and reported to the researcher. The lead researcher followed up on each injury telephonically every week to register an accurate return-to-play date. Time-loss match injuries (an injury occurring during a match which resulted in a player being absent following said match for more than 24 hours of rugby training or match-play)[34] were recorded using a standardised injury data collection form designed by BokSmart, in accordance with the Consensus Statement on injury definitions and data collection procedures for studies of injuries in rugby union (Appendix II).[34]

A total of 210 participants were tested over the eighteen weeks (some players were tested once, twice or three times on varying occasions), and six teams in the control group (three different schools) and five teams in the intervention group (three different schools) were followed over the season to track injuries (Figure 8.1). The dropout of tested participants throughout the trial was due to school and extramural commitments of the players. None of the teams dropped out during the season for the injury surveillance part of the study.

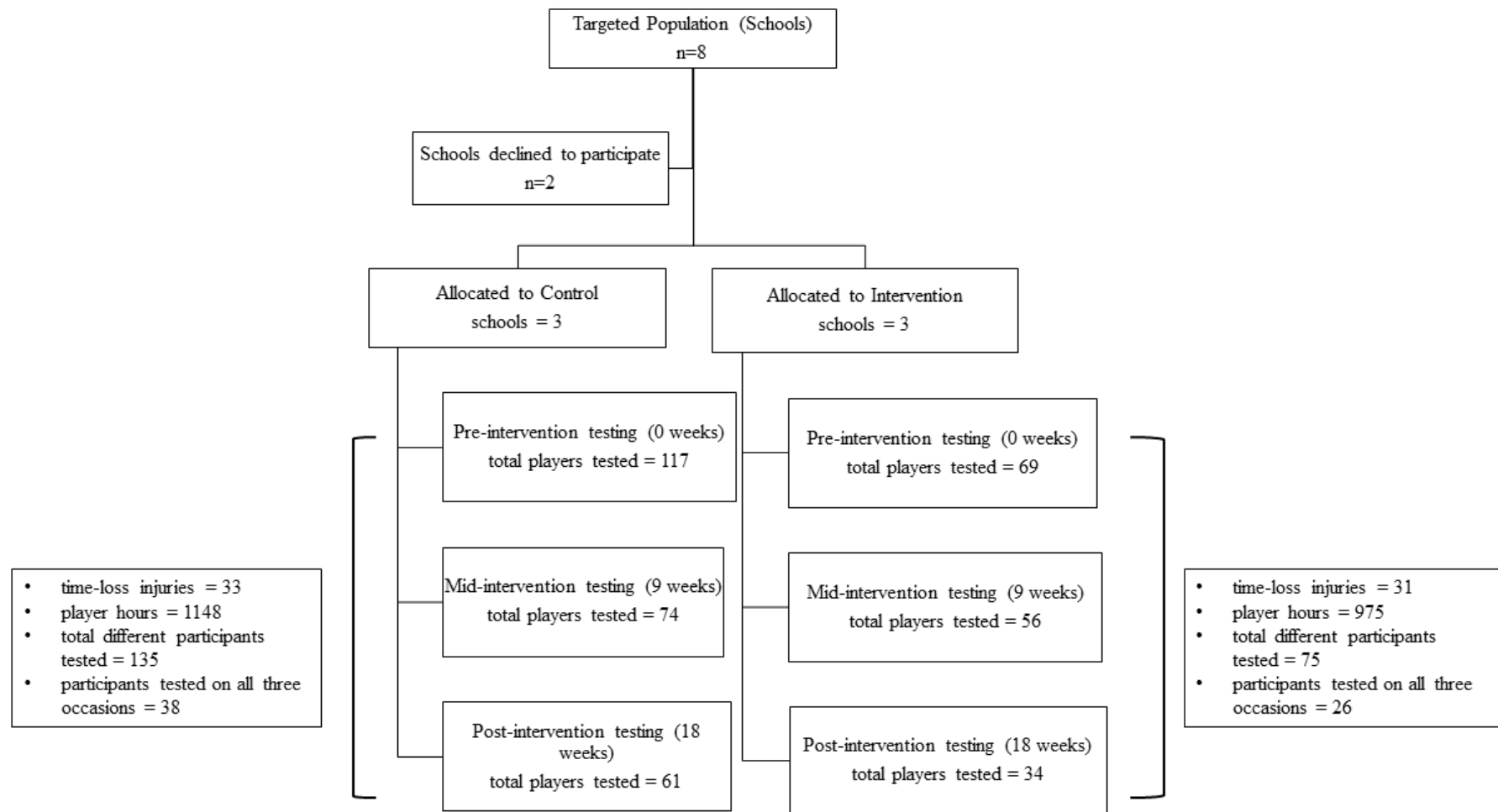


Figure 8.1: Flow diagram of participants enrolled and tested during the cRCT over the eighteen weeks.

Statistical Analyses

Descriptive statistics on the players in each group were performed using means, standard deviations and an independent samples T-test. The differences in Musculoskeletal Screening Assessment scores and FMS scores between the intervention and control group at the different time-points were determined using a linear mixed model analysis, adjusting for baseline measures and maturation status (using the Mirwald calculation to determine years after peak height velocity).[33] The linear mixed model accounted for players missing a testing session and adjusting for this.

For the individual FMS assessment scores (because the data was ordinal), the score was first dichotomised (two categories: ≤ 2 ; 3), and then generalised estimating equations were performed to determine the intervention effect at the different time-points, adjusting for baseline measures and maturation status producing an odds ratio (OR) with 95% confidence intervals (95% CI).

Intention-to-Treat (ITT) analysis was performed using the injury data to calculate the injury incidence density (IID) as the number of injuries per 1,000 player hours with corresponding 95% CI [34] for the control and intervention group, separately. A survival analysis was then performed to determine differences between the two groups (using a Kaplan Meier log rank). All data analyses were performed using IBM SPSS Statistics 24 (2016) and a significance level of $p < 0.05$ was accepted for all statistical analyses.

Results

The descriptive characteristics of the players in the two groups were not significantly different at baseline (Table 8.1).

Table 8.1: Summary and comparisons in the player characteristics between the intervention (n = 69) and control (n = 113) groups at baseline. (mean \pm standard deviation; PHV – peak height velocity). P-value determined using an independent samples T-test.

Trial arm	Intervention	Control	p-value
Age (years)	15.8 (\pm 0.3)	15.8 (\pm 0.2)	0.183
Stature (cm)	176.2 (\pm 6.9)	174.9 (\pm 7.1)	0.207
Body Mass (kg)	74.3 (\pm 11.9)	75.5 (\pm 13.4)	0.529
Maturation Status (years after PHV)	1.7 (\pm 0.6)	1.6 (\pm 0.6)	0.474

Risk profiles

There were no significant differences between the two groups in the FMS composite score or in the individual FMS assessment scores (Supplementary Table 8.1). There were two significant differences in the Musculoskeletal Screening Assessment scores (lumbar flexion and Thomas hip test scores) at the eighteen week time-point (Table 8.2). While the change in the lumbar flexion test score represented an improvement (decrease) in risk profile, the change in the Thomas hip test score represented a decrement (increase) in risk profile.

Table 8.2: Differences in the Musculoskeletal Screening Assessment scores and FMS composite score between the intervention and control group at 9 and 18 weeks. (R – Right appendage; L – Left appendage) (*sign changed from a negative to a positive sign to ensure all results are intuitive to represent a beneficial difference)

Assessment	Difference between Intervention and Control			
	9 Weeks		18 Weeks	
	Difference [95% CI]	p-value	Difference [95% CI]	p-value
FMS Composite Score (AU)	0.8 (-1.0 – 2.6)	0.305	-0.2 (-2.0 – 1.6)	0.800
Sit and Reach (cm)	2.0 (-1.2 – 5.1)	0.165	0.7 (-2.4 – 3.9)	0.596
Lumbar Flexion (cm)*	0.7 (-0.2 – 1.6)	0.111	1.4 (-0.3 – 2.4)	0.011
Lumbar Extension (cm)*	1.4 (-1.1 – 4.0)	0.210	-0.3 (-2.9 – 2.2)	0.758
Active Knee Extension R (°)*	-0.4 (-4.8 – 3.9)	0.847	4.1 (-0.8 – 8.9)	0.100
Active Knee Extension L (°)*	-2.1 (-8.0 – 3.8)	0.429	2.9 (3.1 – 9.0)	0.300
Thomas Hip R (°)*	-1.0 (-4.1 – 2.2)	0.481	-2.0 (-5.3 – 1.1)	0.181
Thomas Hip L (°)*	-1.0 (-3.7 – 1.7)	0.482	-3.7 (-6.8 – -0.5)	0.022
Thomas Knee R (°)*	-5.6 (-20.0 – 8.9)	0.449	4.3 (-15.8 – 24.3)	0.654
Thomas Knee L (°)*	1.9 (-3.6 – 7.4)	0.442	3.0 (-2.7 – 8.6)	0.270
Hip External Rotation R (°)	-0.5 (-9.5 – 8.5)	0.893	-1.5 (-10.5 – 7.4)	0.678
Hip External Rotation L (°)	-0.8 (-12.4 – 10.8)	0.864	0.1 (-3.2 – 3.4)	0.949
Hip Internal Rotation R (°)	0.5 (-3.8 – 4.9)	0.777	-2.1 (-5.4 – 1.3)	0.222
Hip Internal Rotation L (°)	2.9 (-4.8 – 10.7)	0.455	4.5 (-3.4 – 12.4)	0.262
Ankle Dorsiflexion Lunge R (cm)	-1.5 (-6.6 – 3.7)	0.475	-0.1 (-5.3 – 5.0)	0.944
Ankle Dorsiflexion Lunge L (cm)	-1.5 (-7.0 – 4.1)	0.502	0.2 (-5.2 – 5.7)	0.911
Shoulder External Rotation R (°)	-1.7 (-15.9 – 12.5)	0.817	9.0 (-7.7 – 25.6)	0.290
Shoulder External Rotation L (°)	-6.1 (-15.1 – 2.9)	0.146	0.8 (-9.9 – 8.2)	0.836
Shoulder Internal Rotation R (°)	9.9 (-9.4 – 29.2)	0.235	-0.3 (-19.5 – 18.9)	0.969
Shoulder Internal Rotation L (°)	7.8 (-10.5 – 26.1)	0.307	-2.6 (-20.7 – 15.5)	0.721

Injury Incidence Density

The control group had 33 injuries and an exposure of 1147 player match hours, and the intervention group had 31 injuries with an exposure of 975 player match hours. The match time-loss IID (95% CI) for the control group was 28.8 (95%CI: 18.9 – 38.6) injuries per 1,000 player hours, and for the intervention group it was 31.8 (95%CI: 23.6 – 43.0) injuries per 1,000 player hours. Using survival analysis, the mean exposure before a player sustained an injury for the control group was 10.5 (95%CI: 9.7 – 11.3) player match hours, compared to the intervention group that was 10.7 (95%CI: 9.9 – 11.4) player match hours (Figure 8.2). This difference was not significantly different ($p = 0.749$, using ITT analysis).

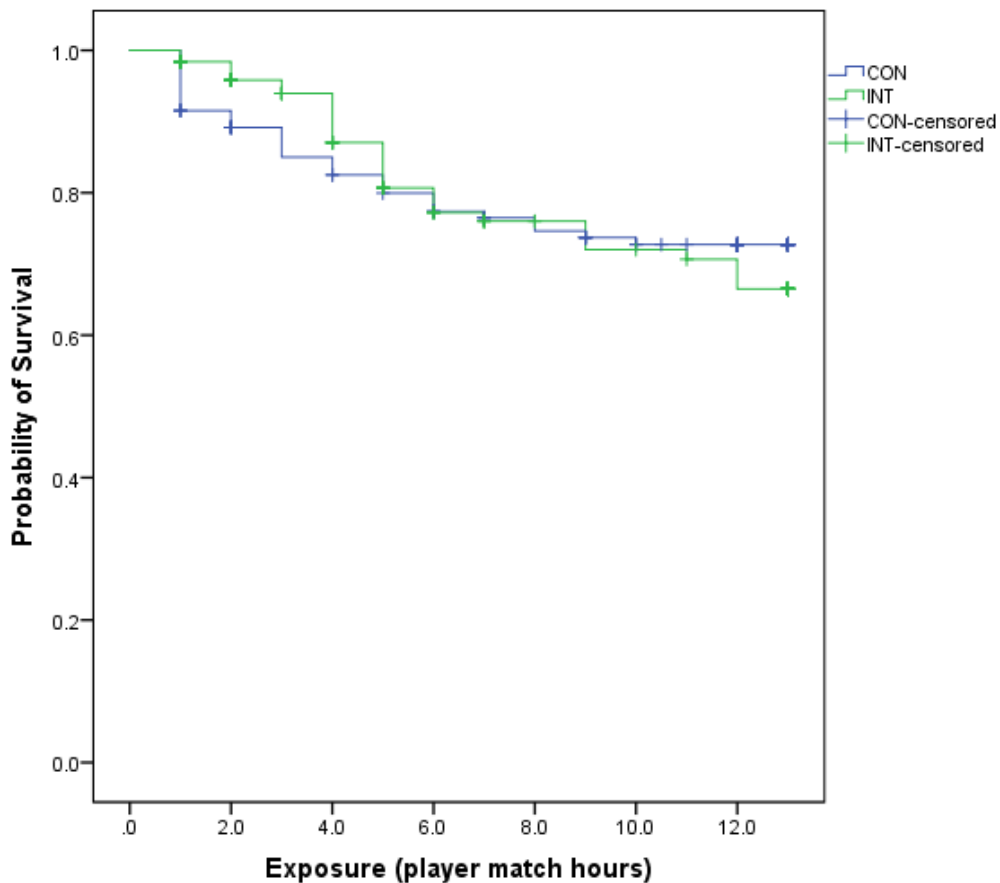


Figure 8.2: Survival analysis of the injury data for the control and intervention groups over the duration of the cRCT ($p = 0.749$). (CON – Control group; INT – Intervention Group)

Discussion

Out of the twenty risk profile assessments, after eighteen weeks the *Safe Six* intervention was associated with: an improvement in lumbar flexion score; a decrease in range of motion of the

hip (Thomas hip score), and; no changes in the composite FMS score. Therefore, it was also expected that there would be no differences in injury rates between the two groups. However, it should be noted that this study was not powered to detect changes in IID.

The Musculoskeletal Screening Assessments that tested the range of motion (ROM) showed equivocal findings. While one ROM measure score improved significantly following the intervention, another one deteriorated significantly. The improvement in the lumbar flexion ROM score could be attributed to the combined nature of the *Safe six* exercises and general stretching exercises, however, none of the exercises specifically targeted the lumbar region. Therefore, it is possible that the increase in lumbar flexion was a chance finding and was not related to the intervention. The decrement in Thomas hip score, however, could be attributed to an increase in muscle strength in the quadriceps, and as a result, loss of range of motion or, it could also be a chance finding not related to the intervention. The *Safe Six* intervention exercises incorporated multiple exercises targeting these specific muscles. Injuries to the lower limbs are common in youth and senior rugby,[7, 35] and therefore the improved range of motion of the hip and lower limb area is important, but so is strength improvement. The exercises included in the *Safe Six* included two lunges recruiting the hamstrings, quadriceps and the muscles around the ankle joints, and the dynamic reaches could all have contributed to the lumbar flexion results. All these exercises should have contributed to an improvement in Thomas hip results too. Thus, it is unclear why the *Safe Six* did not show consistent improvements in these 2 individual primary outcomes in this group of youth rugby players, at eighteen weeks.

Unexpectedly, there were no changes in the FMS scores (both composite and individual) as a result of the intervention. Similarly to the Musculoskeletal Screening Assessment scores, it was hypothesised that the FMS scores would be significantly different between the two groups as a result of the exercises performed in the *Safe Six*, and would, therefore, result in beneficial changes in motor control and ROM. The implications of no changes in FMS scores would imply there would be no change in IID. As this study showed, there was no difference in IID (the study was, however, not statistically powered to detect changes in IID). The control group had an IID of 29 time-loss injuries per 1000 player hours and the intervention group had an IID of 32 time-loss injuries per 1000 player hours. These IID's are comparable to findings in other youth cohorts. Previous studies have shown IID's ranging between 24 – 35 time-loss injuries per 1000 player hours.[2, 3, 12, 36] Our study only looked at match injuries only, and therefore

it is unknown what the effect of the *Safe Six* intervention might have been on training injuries. The *Safe Six* programme is a comprehensive warm-up and could reduce training injuries as it recruits most muscles required for rugby training. However, it must be noted that the training IID is low in rugby and therefore would not make a large contribution to a potential preventive effect.[7]

As illustrated above, there was little improvement in primary outcome scores following the *Safe Six* intervention, and therefore, adjustments to the programme should be investigated. A comparably effective exercise-based intervention in youth rugby has been implemented recently in England. The main difference between this intervention and the *Safe Six* intervention was that the English intervention included a neck strengthening component and exercise progressions throughout the season.[12] This neck strengthening component has been associated with reductions in concussion incidences[12] and if added to the *Safe Six*, could potentially increase its effectiveness in reducing IID in particular.

Limitations

This study was implemented in well-resourced rugby-playing schools, and therefore the application in under-resourced schools might produce different results. Also with twenty different assessments performed to determine changes over time between groups, there could have been statistical chance findings as a result of multiple testing. Moreover, the study was not powered for finding statistical differences between the control and intervention group for the IID. Another limitation is that compliance with the programme was not quantified, and the warm-ups of the control groups were not assessed to determine if they were performing any of the *Safe Six* exercises.

Practical Implications

The BokSmart *Safe Six* programme is simple, time-efficient and requires no equipment. However, the intervention showed minimal effectiveness. The BokSmart *Safe Six* should potentially include a neck strengthening component (as shown effective in decreasing concussion IID in another injury prevention programme).[12] Injury surveillance should continue for re-evaluation to occur before further promotion of the programme is advised.

Conclusion

The BokSmart *Safe Six* improved the lumbar flexion score and decreased the hip range of motion (i.e. the Thomas hip score) significantly after an 18 week-long intervention. BokSmart should investigate adjusting the *Safe Six*, such as incorporating a neck strengthening component, to improve the effectiveness of the *Safe Six* going forward.

References

1. Gall FL, Carling C, Reilly T, Vandewalle H, Church J, Rochcongar P. Incidence of injuries in elite French youth soccer players. *Am J Sports Med.* 2006;34(6):928-38.
2. Haseler CM, Carmont MR, England M. The epidemiology of injuries in English youth community rugby union. *Br J Sports Med.* 2010;44(15):1093-99.
3. Palmer-Green DS, Stokes KA, Fuller CW, England M, Kemp SPT, Trewartha G. Match injuries in English youth academy and schools Rugby Union: an epidemiological study. *Am J Sports Med.* 2013;41(4):749-55.
4. World Rugby. Year in Review 2016. 2016 [cited 2018 June 07]. <http://www.worldrugby.org/documents/annual-reports?lang=en>.
5. Brown J, Verhagen E, Viljoen W, et al. The incidence and severity of injuries at the 2011 South African Rugby Union (SARU) Youth Week tournaments. *S Afr J Sports Med.* 2012;49-54.
6. Burger N, Lambert MI, Viljoen W, Brown JC, Readhead C, Hendricks S. Tackle-related injury rates and nature of injuries in South African Youth Week tournament rugby union players (under-13 to under-18): an observational cohort study. *BMJ Open.* 2014;4(8).
7. Williams S, Trewartha G, Kemp S, Stokes K. A meta-analysis of injuries in senior men's professional Rugby Union. *Sports Med.* 2013;43(10):1043-55.
8. Gabbe BJ, Branson R, Bennell KL. A pilot randomised controlled trial of eccentric exercise to prevent hamstring injuries in community-level Australian Football. *J Sci Med Sport.* 2006;9(1-2):103-09.
9. Naish R, Burnett A, Burrows S, Andrews W, Appleby B. Can a specific neck strengthening program decrease cervical spine injuries in a men's professional Rugby Union team? A retrospective analysis. *J Sports Sci Med.* 2013;12(3):542-50.
10. McHugh MP, Tyler TF, Mirabella MR, Mullaney MJ, Nicholas SJ. The effectiveness of a balance training intervention in reducing the incidence of noncontact ankle sprains in high school football players. *Am J Sports Med.* 2007;35(8):1289-94.
11. Sewry N, Verhagen E, Lambert M, et al. Exercise-based interventions for injury prevention in tackle collision ball sports: a systematic review. *Sports Med.* 2017:1-11.
12. Hislop MD, Stokes KA, Williams S, et al. Reducing musculoskeletal injury and concussion risk in schoolboy rugby players with a pre-activity movement control exercise programme: a cluster randomised controlled trial. *Br J Sports Med.* 2017;51:1140-46.
13. Attwood MJ, Roberts SP, Trewartha G, England ME, Stokes KA. Efficacy of a movement control injury prevention programme in adult men's community rugby union: a cluster randomised controlled trial. *Br J Sports Med.* 2017: 10.1136/bjsports-2017-098005.
14. Sewry N, Verhagen E, Lambert M, van Mechelen W, Brown J. Evaluation of the effectiveness and implementation of the BokSmart Safe Six injury prevention programme: a study protocol. *Inj Prev.* 2017;23:428.

15. Sewry N, Verhagen E, Lambert M, van Mechelen W, Brown J. Players' and coaches' knowledge and awareness of the BokSmart Safe Six injury prevention programme: an ecological cross-sectional questionnaire study. *BMJ Open* 2017;7(11).
16. Brooks J, Fuller C, Kemp S, Reddin D. Epidemiology of injuries in English professional rugby union: part 1 match injuries: *Br J Sports Med*. 2005;757-66.
17. Andrew N, Gabbe BJ, Cook J, et al. Could targeted exercise programmes prevent lower limb injury in community Australian football? *Sports Med*. 2013;43(8):751-63.
18. Filipa A, Byrnes R, Paterno MV, Myer GD, Hewett TE. Neuromuscular training improves performance on the Star Excursion Balance test in young female athletes. *J Orthop Sports Phys Ther*. 2010;40(9):551-58.
19. Kiesel K, Plisky P, Butler R. Functional movement test scores improve following a standardized off-season intervention program in professional football players. *Scand J Med Sci Sports*. 2011;21(2):287-92.
20. Tee JC, Klingbiel J, Collins R, Lambert M, Coopoo Y. Preseason Functional Movement Screen component tests predict severe contact injuries in professional rugby union players. *J Strength Cond Res*. 2016;30(11):3194-203.
21. Duke SR, Martin SE, Gaul CA. Preseason Functional Movement Screen predicts risk of time-loss injury in experienced male Rugby Union athletes. *J Strength Cond Res*. 2017;31(10):2740-47.
22. Brukner P, Khan KM. Low back pain. in: *Clin Sports Med*. McGraw Hill Companies Inc. 2001(2nd eds.):330-59.
23. Cook G, Burton L, Hoogenboom B. Pre-participation screening: the use of fundamental movements as an assessment of function – part 1. *N Am J Sports Phys Ther: NAJSPT*. 2006;1(2):62-72.
24. Cook G, Burton L, Hoogenboom B. Pre-participation screening: the use of fundamental movements as an assessment of function – part 2. *N Am J Sports Phys Ther: NAJSPT*. 2006;1(3):132-39.
25. Cools AM, De Wilde L, Van Tongel A, Ceysens C, Ryckewaert R, Cambier DC. Measuring shoulder external and internal rotation strength and range of motion: comprehensive intra-rater and inter-rater reliability study of several testing protocols. *J Shoulder Elbow Surg*. 2014;23(10):1454-61.
26. Dennis RJ, Finch CF, Elliott BC, Farhart PJ. The reliability of musculoskeletal screening tests used in cricket. *Phys Ther Sport*. 2008;9(1):25-33.
27. Gabbe BJ, Bennell KL, Wajswelner H, Finch CF. Reliability of common lower extremity musculoskeletal screening tests. *Phys Ther Sport*. 2004;5(2):90-97.
28. Lin J-j, Yang J-L. Reliability and validity of shoulder tightness measurement in patients with stiff shoulders. *Man Ther*. 2006;11(2):146-52.
29. Readhead C, Viljoen W, Suter J. Safety in the playing environment document, BokSmart. 2015.
30. Hayes RJ, Bennett S. Simple sample size calculation for cluster-randomized trials. *Int J Epidemiol*. 1999;28(2):319-26.
31. Gabbe BJ, Bennell KL, Finch CF, Wajswelner H, Orchard JW. Predictors of hamstring injury at the elite level of Australian football. *Scand J Med Sci Sports*. 2006;16(1):7-13.
32. Durnin J, Womersley J. Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged 16 to 72 years. *Br J Nutr*. 1974:77-97.
33. Mirwald RL, Baxter-Jones AD, Bailey DA, Beunen GP. An assessment of maturity from anthropometric measurements. *Med Sci Sports Exerc*. 2002;34(4):689-94.

34. Fuller C, Molloy M, Bagate C, et al. Consensus statement on injury definitions and data collection procedures for studies of injuries in rugby union. *Br J Sports Med.* 2007;328-31.
35. Freitag A, Kirkwood G, Scharer S, Ofori-Asenso R, Pollock AM. Systematic review of rugby injuries in children and adolescents under 21 years. *Br J Sports Med.* 2015;49(8):511-19.
36. Archbold HAP, Rankin AT, Webb M, et al. RISUS study: Rugby Injury Surveillance in Ulster Schools. *Br J Sports Med.* 2017;51(7):600-06.

Supplementary Table 8.1: Individual FMS assessment scores. (OR – Odds Ratio with 95% confidence intervals)

Assessment	OR [95% CI]	9 Weeks p-value	OR [95% CI]	18 Weeks p-value
FMS Individual Tests				
Overhead Squat	0.62 (0.92 – 1.01)	0.274	0.88 (0.32 – 2.40)	0.801
Single Leg Hurdle Step	1.12 (0.44 – 2.84)	0.808	2.01 (0.63 – 6.40)	0.239
Single Leg Lunge	1.04 (0.45 – 2.39)	0.935	1.76 (0.67 – 4.67)	0.254
Shoulder Mobility	0.53 (0.21 – 1.32)	0.172	0.65 (0.22 – 1.93)	0.441
Straight Leg Raise	0.52 (0.23 – 1.21)	0.128	0.86 (0.28 – 2.06)	0.585
Push Up	1.11 (0.47 – 2.63)	0.812	1.57 (0.62 – 3.94)	0.338
Rotary Stability	-	-	-	-

CHAPTER 9:

GENERAL DISCUSSION

The primary purpose of this thesis was to evaluate the effectiveness of the BokSmart *Safe Six* injury prevention programme for youth rugby players in South Africa through the “Sequence of Prevention”.

Seven research questions were addressed in this thesis to answer this larger research question on the effectiveness of the BokSmart *Safe Six* injury prevention programme. These chapters extended through all four steps of the “Sequence of Prevention”: providing an overview of the youth rugby injury rates and severity of injuries, the aetiology of injuries, the development of an injury prevention programme; and finally the establishment of efficacy and effectiveness of the *Safe Six* programme.

Main Findings

The BokSmart *Safe Six* was designed and launched in 2014 by BokSmart, and in 2015 the research team was given the task of assessing the effectiveness of the *Safe Six* in youth rugby. Although the *Safe Six* programme had already been designed and implemented, this thesis used the “Sequence of Prevention”[1] as a conceptual model to describe the various steps needed to bring about effective sports injury prevention in youth rugby. This section discusses the main findings of each chapter as explored in each stage of the model. It also acknowledges the limitations of the studies conducted, the practical implications and makes suggestions for future research in the area to address unanswered and arising questions.

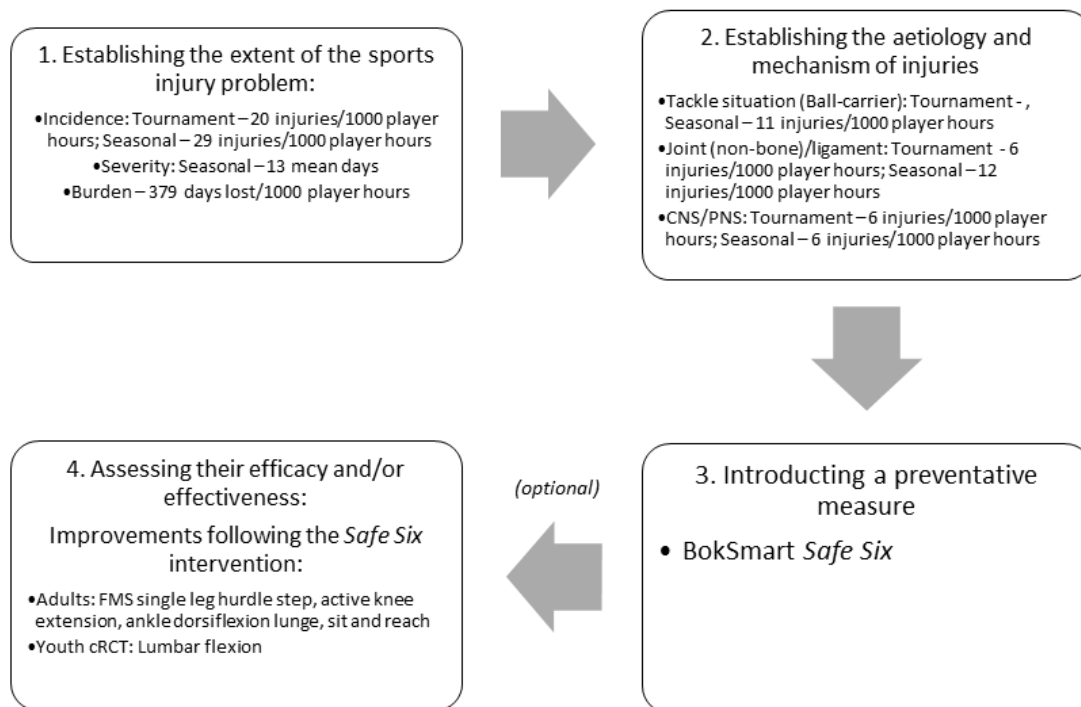


Figure 9.1: “Sequence of Prevention” model as explored in the thesis. (CNS – central nervous system; PNS – peripheral nervous system; FMS – Functional Movement Screen; cRCT – cluster-randomised controlled trial)

Extent and Severity of South African Youth Rugby Injuries

The extent of the problem of injury incidence density (hereinafter referred to as “injury rate”) and aetiology and mechanism of injury in rugby players, and specifically in youth players, is covered in chapters 2 and 7 (step 1 and 2 of the model, respectively).

The injury rate of injuries in senior rugby players has been well documented, but less so in the youth.[2, 3] In the South African context, though, there is limited research on rugby injuries, particularly studies that have used definitions from the consensus statement on rugby injury definitions.[4, 5] In chapter 2, tournament time-loss match injury rates (time-loss match injury rate, hereafter referred to as injury rate) were identified in youth players of ages under-13 to under-18. The tournament injury rate was lower than youth cohorts from previous studies. The tournament injury rate was also lower compared to the injury rate over a season (chapter 7) in under-16 players, which was similar to other seasonal youth cohorts.[6-8] Both studies used prospective cohort designs. The tournament data suggested an increasing trend in injury rate, justifying the need for an intervention. These injury rate differences between tournament and seasonal data in the South African cohort are important, as they give insight into the differences between South African tournament and season rugby.

The season injury burden (days lost per 1000 player hours) described in chapter 7 is lower than that seen in other youth cohorts. The injury burden in chapter 7 was 379 days lost per 1000 player hours, compared to an English youth cohort with an injury burden of 862 days lost per 1000 player hours.[9] This lower injury burden in the South African under-16 players is explained by a lower severity at a similar injury rate, which equates to a relatively lower injury burden. Therefore, the injury rate and injury burden differences could be explained by players being exposed to better coaching and being better physically conditioned compared to other cohorts, however, chapter 7 was a small sample size and future research should investigate this.

Aetiology and Mechanisms of South African Youth Rugby Injuries

The aetiology and mechanism of injury (step 2 of the “Sequence of Prevention”) in the youth tournament setting (chapter 2) were similar to those over an entire season and in multiple teams. The tackle situation (both ball-carrier and tackler) had the highest injury rate of all phases of play, as has been reported in youth and senior cohorts.[2, 3] A subsequent study in a similar South African cohort has shown an association with tackle technique and tackle-related injuries,[10] indicating that improvement in technique could possibly reduce these injuries.

The type of the injuries sustained at the tournaments was different compared to those sustained over a season. Central/Peripheral nervous system (CNS/PNS) injuries were the most frequently reported injuries at the tournaments, but over a season it was joint (non-bone)/ligament injuries, which is more similar to that of other youth studies.[8] The majority of CNS/PNS injuries are comprised of concussions. However, the CNS/PNS injury rate appears to be increasing when comparing older studies with more recent studies.[9, 8] This phenomenon has been attributed to the increased awareness (through national and international rugby unions) and reporting of confirmed concussions and suspected concussions.[9, 11]

The final associated risk factor investigated was the match quarter when injuries occurred. During the tournaments, the injuries occurred towards the end of the match (chapter 2), however, during the season the injury rate was highest in the beginning of the match (chapter 7). Previous data showed similar results to the tournament data,[3] which has led to some recommendations (see further research and practical implications section in this General Discussion). However, the *Safe Six* did not target either of these risk factors, which could explain the lack of effectiveness in changes in injury risk profiles, especially the lack of focus on CNS/PNS injuries.

Previous Exercise-Based Injury Prevention Programmes

The systematic review in chapter 3 described previous studies that had used an exercise-based intervention in an attempt to prevent injuries in collision sports (step 3 of the model). This was an important step in the process, as the BokSmart *Safe Six* was developed prior to the initiation of this project and was based on clinical practices and previous research. The systematic review found nine studies that met the inclusion criteria, and furthermore, only seven effective interventions in collision sports. However, these studies were of a variety of methodological qualities, sporting codes and age groups, making an overall interpretation difficult. These effective interventions included balance training and eccentric hamstring curls, both of which are supported by evidence in other sports.[12] This indicates preventive qualities of such interventions, even though they were performed in low-quality studies in these collision sports.[12] An important factor determining intervention effectiveness in these exercise programmes was compliance, and increasing compliance should increase effectiveness.[13] Therefore, to increase compliance, the adoption barriers need to be reduced as much as possible.

Subsequent to the completion of the systematic review (chapter 3), a high-quality exercise-based RCT was conducted in both youth and adult community rugby players in England.[14, 9] This intervention was associated with reductions in injury rate and particularly concussions.[14, 9] This multi-component exercise-based programme included various levels of difficulty for specific age groups of players and further progression of difficulty throughout the season.[14, 9]

Following the findings from the review, the BokSmart *Safe Six* can be compared to these programmes, and specifically the effective components of exercise programmes. The BokSmart *Safe Six* was designed as a warm-up and therefore can be included in regular practice, requiring no equipment, and therefore potentially increasing compliance.[15] The exercises included in the *Safe Six* had balance exercises and eccentric hamstring curls, that have also been shown to be associated with reductions in injury rate in collision sports.[16, 17] However, the *Safe Six* is missing an exercise component focusing on the neck.[18] This should be considered, as there is a potential association between exercises that strengthen the neck muscles and reductions in concussion injuries.[9] These comparisons between the *Safe Six* and other effective injury prevention programmes indicate that the *Safe Six* should have been associated with a decrease in injury rates. However, the studies included in the review (chapter

3) did not assess the effect of exercise interventions on intermediary measures of injury such as FMS and Musculoskeletal Screening Assessments.

Was the BokSmart *Safe Six* Effective?

Assessing the BokSmart Safe Six using Injury Risk Profiles and Injury Rate

A challenge in intervention evaluation research within injury prevention trials is the use of many different outcomes to determine the efficacy of the intervention. To see a significant change in direct injury rate, the trial is required to be performed over a long enough follow-up period and to use a sufficiently powered sample with injury as the primary outcome.[19] To overcome this issue of long study periods sometimes other measures associated with injury are used. The Functional Movement Screening (FMS) protocol and the BokSmart Musculoskeletal Screening Assessment are two such intermediary measures used to assess injury risk.[20-23] Previous studies have established the association between motor control measures and injury, where motor control outcomes mediate injury risk and can thus be seen as a proxy for injury risk.[24-27] The underlying assumption is that an exercise intervention can improve motor control patterns (broad term for neuromuscular control, strength, muscle mass) and range of motion (ROM), and therefore, improve FMS scores or Musculoskeletal Screening Assessment scores.[28] Following the motor control and ROM changes elicited from an exercise intervention and its associated FMS score, injury rates are then assumed to be reduced.[9] There have been studies showing associations between decreased FMS composite scores and either time-loss injuries, increased injury burden or injury severity.[29, 27, 26] However, so far no direct link between FMS (or Musculoskeletal Screening Assessment) scores and a change in injury rate has been observed in a randomised controlled trial (RCT).

The BokSmart *Safe Six* exercises were assessed in two different cohorts in different study settings: i.e. in non-rugby playing adults under laboratory conditions and in youth rugby players in a more real-world setting. To assess the effectiveness of the *Safe Six*, the FMS scores were measured in both cohorts.

The BokSmart *Safe Six* programme was not associated with improvements in the FMS composite score in both cohorts. In the adult cohort, the single leg hurdle step individual FMS assessment score was associated with an improvement as a result of the *Safe Six*. The lack of improvements in FMS scores in the cRCT (chapter 8), however, indicate that there was a no effect of the *Safe Six* on a youth rugby cohort, one of the targeted populations for the *Safe Six*.

In contrast, the *Safe Six* was associated with improvements in some of the Musculoskeletal Screening Assessment scores in both cohorts. In the adult cohort, the active knee extension score and ankle dorsiflexion lunge scores improved in the intervention, compared to the control period (chapter 5). The lumbar flexion score improved in the youth cohort significantly (chapter 8). Most of the changes in Musculoskeletal Screening Assessment scores can be explained by understanding the muscle groups recruited by the exercises included in the *Safe Six*: i.e. shuttle runs (change of direction recruiting various lower limb structures), two different types of lunges (leading to quadriceps and hamstring muscle recruitment), dynamic reaches (leading to ankle and lower limb muscles recruitment, shoulder muscle recruitment), eccentric hamstring curls and rotational push-ups (shoulder muscle recruitment). The results of the Thomas hip score in the youth cohort appear to contradict the goal of the exercises (such as the lunges), as it decreased.

Referring to the conceptual model of changes occurring due to an exercise intervention, this lack of effect could be attributed to two possibilities: (1) the BokSmart *Safe Six* did not elicit the motor control and/or ROM changes expected from the exercise intervention; (2) the *Safe Six* elicited changes in motor control and/or ROM, but these changes did not result in improved FMS or Musculoskeletal Screening Assessment scores. If the first assumption is true, and the model is correct, then the *Safe Six* would not result in a decrease in injury either, making the *Safe Six* an ineffective injury prevention programme. However, if the second assumption is true, the *Safe Six* could be eliciting changes in motor control and/or ROM, which may result in decreased injury risk, but the measurement tools applied do not measure changes adequately in FMS or Musculoskeletal Screening Assessment scores. Further investigation into the validity of the FMS and Musculoskeletal Screening Assessment (including the assessment of sensitivity to change), as intermediary measures for injury, should be performed (see Recommendations for Future Research).

The *Safe Six* intervention in the youth study (due to its pragmatic nature) was not sufficiently powered to detect changes in match time-loss injury rates, and therefore the injury rates results cannot be interpreted further (chapter 8). Overall, the *Safe Six* interventions in youth and adult cohorts were associated with modest positive improvements in Musculoskeletal Screening Assessment scores, and minimal-to-no improvements in FMS scores. It can, therefore, be concluded that the *Safe Six* had little injury preventive qualities in this study.

Dissemination of the BokSmart Safe Six

The BokSmart *Safe Six* was launched in 2014, and the reach of the marketing performed by BokSmart regarding the programme needed to be assessed to determine the awareness of the programme and how the information had been disseminated. Whilst this is not a step in the “Sequence of Prevention”, it is of importance to BokSmart and intervention implementation research, and is a component of recent research models such as the TRIPP model.[30] Chapter 4 examined the awareness and knowledge of players and coaches of the BokSmart *Safe Six* over three years, including the specific targeted marketing year. Unsurprisingly, the overall awareness was higher in coaches than players (as BokSmart is a coach-targeted programme),[11] but the awareness in both players and coaches increased significantly following the targeted marketing approach, compared to the launch year. This was maintained after the marketing year. Players whose coaches were aware of the programme were associated with an increased chance of being aware of the programme. This knowledge transfer from coach-to-player is important to evaluate, as this knowledge transfer is the foundation of the BokSmart coach-targeted model.[11] This concept has already been investigated on a large scale in South Africa. Using injury prevention behaviours, the majority of players reported receiving their information from either their coaches or physiotherapists, illustrating the coach-player knowledge transfer.[31]

In addition to an increased awareness following the targeted-marketing period, reported usage of the programme also increased following this marketing period. The coaches and players reported that they had received most of their information about the *Safe Six* from rugby unions, coaches and social media. All these sources are affordable and an easy means of disseminating an injury prevention programme. The associated increase in reported usage of the BokSmart *Safe Six* following cost-effective social media marketing seems to indicate that the *Safe Six* could be widely adopted in future.

Limitations

There were limitations with each of the studies. However, it must first be reiterated that the research team was only approached to assess the effectiveness of the *Safe Six* programme after the *Safe Six* had been designed and launched by BokSmart. This limited the evaluation of the effectiveness of the *Safe Six* from the start, as no research model could be followed to develop, evaluate and implement an injury prevention programme from scratch. The research team should have been involved from the beginning, allowing the “Sequence of Prevention” to be

followed in order by the same researchers, and therefore giving the designed programme the best chance of success based on sound evidence, for instance by following the intervention mapping protocol.[32]

The main limitation of evaluating the *Safe Six* was the lack of statistical power to determine a change in injury rates in chapter 8 (at least 13 schools in the intervention and 13 in the control group with each school contributing 570 match exposure hours were required for a cRCT). The *Safe Six* was designed to reduce injuries in rugby players and unfortunately, the trial could not follow enough teams for the season to reach the number of match exposure hours required for statistical power to detect changes in injury rates. Furthermore, the compliance of the intervention group was unknown, and therefore whether or not they completed the intervention programme as prescribed is unknown. The control group could have also been performing some of the exercises, as the programme was freely available, providing a confounder.

The systematic review (chapter 3) that was performed at the time that the research team was approached, showed that few studies had investigated the effects of an exercise-based intervention in sports similar to rugby.[16, 33-36, 17, 18, 37, 15] With so few studies, comparisons are difficult to make, and furthermore, there were multiple sporting types and age groups included. However, there were some effective exercise interventions in contact sports; i.e. eccentric hamstring curls, balance training and landing skills.[35, 17, 37] Furthermore, a well performed study in rugby showing a decrease in injury rate, injury burden and specifically, a decrease in concussion incidence, was completed a year after publication,[9] which would have provided a good rationale for rugby-specific exercise interventions.

The assessment of the dissemination of the BokSmart *Safe Six* using the SA Rugby Youth week tournaments had the limitation of an unknown number of repeat participants (chapter 4). The tournaments included multiple age groups and a sub-group of players continued to be selected for two years in a row and therefore may have completed the questionnaire multiple times, increasing their exposure to the programme. The knowledge transfer from coach to the player was also limited, as a subset of players could not be linked to their coaches. Another limitation was that all data on behaviour was self-reported and not observed, and the questionnaire was based on knowledge and perceptions, which are weak predictors of behaviour.

The injury rate studies (chapter 2 and 7) both showed that the tackle phase of play had the highest injury rate compared to the other phases. However, the analysis did not consider the time spent performing each activity during a match. The tackle is the most commonly occurring

phase during a match, and therefore the hypothesis is not proven that being involved in a tackle is more “dangerous” than the involvement in any other phase of play.

The studies assessing the effectiveness of the BokSmart *Safe Six* had some limitations. The intervention period for the study in adults may have been too short to elicit further changes in the injury risk profiles. Furthermore, the effect of repetitive testing in the adult cohort must be noted. The study of the youth was not sufficiently powered for the statistical interpretation of differences between the control and intervention group for the injury rate. This reduced the ability to make clinical interpretations of the FMS score changes.

Practical Implications

The *Safe Six* was associated with minimal changes in injury risk profiles in the South African youth rugby population and therefore, BokSmart should be cautious when advocating its use (chapter 8). At the same time Boksmart should understand that ‘*absence of evidence does not equal evidence of absence*’. BokSmart may also consider adjusting the *Safe Six*: for example, by adding a neck component in an attempt to reduce concussion injuries.[9]

The injury data from both the season and tournament data have shown that the South African youth rugby player is sustaining a high incidence of lower and upper limb joint (non-bone)/ligament injuries (chapter 2 and 7). Concussion injuries also have a high injury rate and need special attention. Therefore, all medical staff must be trained in identification of the signs and symptoms of concussion to ensure the players with suspected and confirmed concussions are removed from play immediately. These injuries need to be addressed by the medical support teams at schools and provincial level. Prevention programmes implemented by these medical support teams need to focus on these injuries. Following from this, the players are sustaining their injuries during the tackle phase of play (regardless of frequency versus risk, this is where the injuries are occurring). Therefore, tackle techniques in the youth need to be addressed from a young age. The younger the players begin practicing and are being taught the correct tackle technique the lower the injury rate in the tackle phase of play will become. Tackle technique and tackle drills could be added to the *Safe Six* to increase the effectiveness of the programme.

During the tournaments, especially, the timing of the injuries is important for the medical staff working at the tournament (chapter 2). The influx of injuries towards the end of the matches (and these injuries are time-loss therefore generally requiring longer medical assessments than

medical attention injuries) needs to be catered for by potential increases in medical staff. Furthermore, overall the injury rate during the SA Rugby Youth week tournaments is on an upward trend and this should be considered by SA Rugby and BokSmart when planning the medical staff for the tournaments as the medical demand will be increasing too.

In the school setting, the coaches and conditioning staff should be aware of the increase in injuries at the beginning of the match in the first half of the season (chapter 7). The players are potentially not “match-prepared” at the beginning of the season, and therefore friendly pre-season matches could be implemented, and the conditioning staff should ensure the players are contact-ready at the beginning of the season, as this could be a possible contributor to the injuries.

Recommendations for Future Research

Following the limitations and the practical implications from the studies, there are some recommendations for future research to assist in the evaluation of tackle injuries, implementation of the *Safe Six*, and the effectiveness of an adjusted *Safe Six*.

The *Safe Six* may incorporate a neck strengthening component and then be assessed in differently resourced schools in South Africa for its effectiveness in decreasing injury rate and injury burden. There is the incorporation of eccentric hamstring curls in the *Safe Six*, which are known to reduce injuries, indicating a potential injury preventive effect. Therefore, using a cRCT, the adjusted *Safe Six* can be assessed for effectiveness in injury prevention, using a larger sample to ensure statistical power for detecting changes in injury rates (at least 13 schools in the intervention and control groups with each school contributing 570 match exposure hours). These schools were not recruited in our study as the research team wanted a homogenous sample. Compliance must also be measured in the groups and per protocol analysis should be performed to determine the effect of compliance to the *Safe Six*.

Following the cRCT, the barriers and facilitators for the implementation of the *Safe Six* in the intervention schools need to be investigated before further studies are conducted. This could provide much-needed data to increase the usability and uptake of the programme. Using qualitative interviews with the coaches responsible for implementing the *Safe Six* in the intervention schools, the barriers and facilitators can be explored.

The lack of changes in the FMS and Musculoskeletal Screening Assessments following an exercise-based intervention call into question the validity of these measures as intermediary

outcomes. Further research should investigate, using an already proven injury prevention exercise intervention, whether the FMS and Musculoskeletal Screening Assessments do change commensurate with the injury rates. A validity study will assist future researchers and clinicians to use tests that are valid measures of injury.

The tackle phase of play is claimed to be “the most dangerous phase of play” in rugby. However, the evidence is lacking to assess time spent performing each phase of play and evaluating the phases of play and their injury risk according to the frequency of each phase and number of injuries. Pairing video analysis of rugby matches and the corresponding injury data, the injury risk can be determined for all phases of play in rugby. This can also be performed using teams from different levels of play (age groups and skill level) to further investigate this injury risk.

Conclusion

The BokSmart *Safe Six* was associated with minimal changes in injury risk profile scores in youth.

The SA youth rugby cohort had a similar injury rate to other youth cohorts (and in some instances lower), with the joint (non-bone)/ligament and CNS/PNS injuries having the highest injury rate. The systematic review identified only one high-level study (out of three) that was effective for injury prevention, but eccentric hamstring curls, plyometric exercises and balance training appeared to have prevention qualities. The players’ awareness of the BokSmart *Safe Six*, was associated with the awareness of their specific coaches’ awareness and the awareness increased during the targeted-marketing approach.

The youth rugby cohort in South Africa is still in need of an effective intervention, and recent findings indicate a neck strengthening component may increase the effectiveness of the *Safe Six*.

References

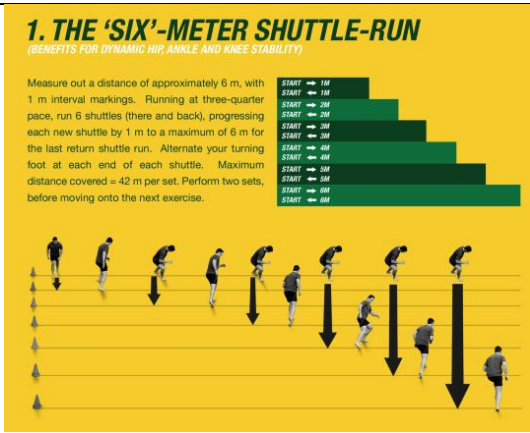
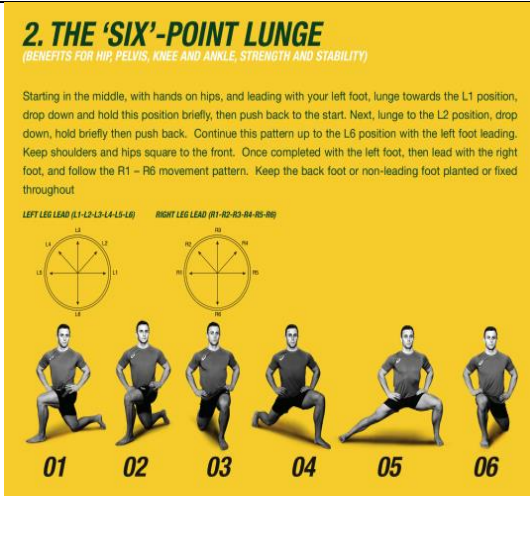
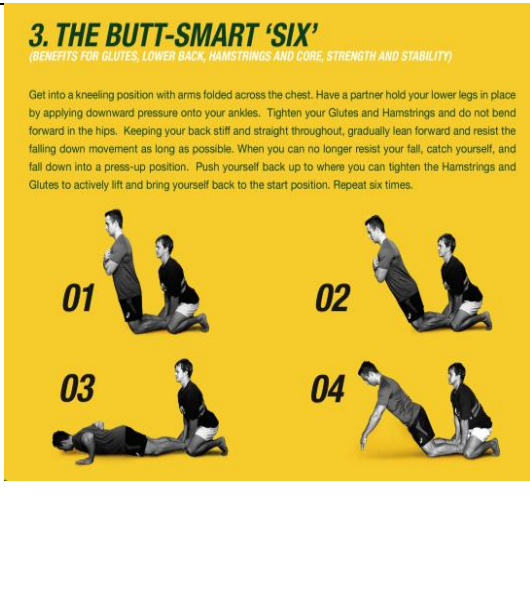
1. van Mechelen W, Hlobil H, Kemper HC. Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. *Sports Med.* 1992;14(2):82-99.
2. Freitag A, Kirkwood G, Scharer S, Ofori-Asenso R, Pollock AM. Systematic review of rugby injuries in children and adolescents under 21 years. *Br J Sports Med.* 2015;49(8):511-19.
3. Williams S, Trewartha G, Kemp S, Stokes K. A meta-analysis of injuries in senior men's professional Rugby Union. *Sports Med.* 2013;43(10):1043-55.
4. Brown J, Verhagen E, Viljoen W, et al. The incidence and severity of injuries at the 2011 South African Rugby Union (SARU) Youth Week tournaments. *S Afr J Sports Med.* 2012;49-54.
5. Mc Fie S, Brown J, Hendricks S, et al. Incidence and factors associated with concussion injuries at the 2011 to 2014 South African Rugby Union Youth Week tournaments. *Clin J Sport Med.* 2016;26(5):398-404.
6. Archbold HAP, Rankin AT, Webb M, et al. RISUS study: Rugby Injury Surveillance in Ulster Schools. *Br J Sports Med.* 2017;51(7):600-06.
7. Haseler CM, Carmont MR, England M. The epidemiology of injuries in English youth community rugby union. *Br J Sports Med.* 2010;44(15):1093-99.
8. Palmer-Green DS, Stokes KA, Fuller CW, England M, Kemp SPT, Trewartha G. Match injuries in English youth academy and schools Rugby Union: an epidemiological study. *Am J Sports Med.* 2013;41(4):749-55.
9. Hislop MD, Stokes KA, Williams S, et al. Reducing musculoskeletal injury and concussion risk in schoolboy rugby players with a pre-activity movement control exercise programme: a cluster randomised controlled trial. *Br J Sports Med.* 2017;51:1140-46.
10. Sobue S, Kawasaki T, Hasegawa Y, et al. Tackler's head position relative to the ball carrier is highly correlated with head and neck injuries in rugby. *Br J Sports Med.* 2017: doi: 10.1136/bjsports-2017-098135
11. Viljoen W, Patricios J. BokSmart – implementing a National Rugby Safety Programme. *Br J Sports Med.* 2012;46(10):692-93.
12. Rössler R, Donath L, Verhagen E, Junge A, Schweizer T, Faude O. Exercise-based injury prevention in child and adolescent sport: a systematic review and meta-analysis. *Sports Med.* 2014;44(12):1733-48.
13. Verhagen E, Finch CF. Setting our minds to implementation. *Br J Sports Med.* 2011;45(13):1015-16.
14. Attwood MJ, Roberts SP, Trewartha G, England ME, Stokes KA. Efficacy of a movement control injury prevention programme in adult men's community rugby union: a cluster randomised controlled trial. *Br J Sports Med.* 2017:doi: 10.1136/bjsports-2017-098005.
15. Verrall GM, Slavotinek JP, Barnes PG. The effect of sports specific training on reducing the incidence of hamstring injuries in professional Australian Rules football players. *Br J Sports Med.* 2005;39(6):363-68.
16. Brooks JH, Fuller CW, Kemp SP, Reddin DB. Incidence, risk, and prevention of hamstring muscle injuries in professional rugby union. *Am J Sports Med.* 2006;34(8):1297-306.
17. McHugh MP, Tyler TF, Mirabella MR, Mullaney MJ, Nicholas SJ. The Effectiveness of a balance training intervention in reducing the incidence of noncontact ankle sprains in high school football players. *Am J Sports Med.* 2007;35(8):1289-94.




18. Naish R, Burnett A, Burrows S, Andrews W, Appleby B. Can a specific neck strengthening program decrease cervical spine injuries in a men's professional Rugby Union team? a retrospective analysis. *J Sports Sci Med.* 2013;12(3):542-50.
19. Hayes RJ, Bennett S. Simple sample size calculation for cluster-randomized trials. *Int J Epidemiol.* 1999;28(2):319-26.
20. Deydre S, Teyhen, Shaffer SW, Lorenson CL, et al. The Functional Movement Screen: a reliability study. *J Orthop Sports Phys Ther.* 2012;42(6):530-40.
21. Kraus K, Schutz E, Taylor W, Doyscher R. Efficacy of the Functional Movement Screen: a review. *J Strength Cond Res.* 2014;28(12):14.
22. Gabbe BJ, Bennell KL, Finch CF, Wajswelner H, Orchard JW. Predictors of hamstring injury at the elite level of Australian football. *Scand J Med Sci Sports.* 2006;16(1):7-13.
23. Gabbe BJ, Bennell KL, Wajswelner H, Finch CF. Reliability of common lower extremity musculoskeletal screening tests. *Phys Ther Sport.* 2004;5(2):90-97.
24. Filipa A, Byrnes R, Paterno MV, Myer GD, Hewett TE. Neuromuscular training improves performance on the Star Excursion Balance test in young female athletes. *J Orthop Sports Phys Ther.* 2010;40(9):551-58.
25. Kiesel K, Plisky P, Butler R. Functional movement test scores improve following a standardized off-season intervention program in professional football players. *Scand J Med Sci Sports.* 2011;21(2):287-92.
26. Tee JC, Klingbiel J, Collins R, Lambert M, Coopoo Y. Preseason Functional Movement Screen component tests predict severe contact injuries in professional rugby union players. *J Strength Cond Res.* 2016;30(11):3194-203.
27. Duke SR, Martin SE, Gaul CA. Preseason Functional Movement Screen predicts risk of time-loss injury in experienced male Rugby Union athletes. *J Strength Cond Res.* 2017;31(10):2740-47.
28. Bodden JG, Needham RA, Chockalingam N. The effect of an intervention program on Functional Movement Screen test scores in Mixed Martial Arts Athletes. *J Strength Cond Res.* 2015;29(1):219-25.
29. Attwood M, Roberts S, Trewartha G, England M, Stokes K. It's not 'who' but 'how badly': The association of Functional Movement Screen Score with injury outcome in community rugby union *Br J Sports Med.* 2017;51(4):290-90.
30. Finch C. A new framework for research leading to sports injury prevention. *J Sci Med Sport.* 2006;9(1-2):3-9.
31. Brown JC, Gardner-Lubbe S, Lambert MI, van Mechelen W, Verhagen E. Coach-directed education is associated with injury-prevention behaviour in players: an ecological cross-sectional study. *Br J Sports Med.* 2016: 10.1136/bjsports-2016-096757.
32. Bartholomew LK, Parcel GS, Kok G. Intervention Mapping: A process for developing theory and evidence-based health education programs. *Health Educ Behav.* 1998;25(5):545-63.
33. Cross KM, Worrell TW. Effects of a static stretching program on the incidence of lower extremity musculotendinous strains. *J Athl Train.* 1999;34(1):11-4.
34. Finch CF, Twomey DM, Fortington LV, et al. Preventing Australian football injuries with a targeted neuromuscular control exercise programme: comparative injury rates from a training intervention delivered in a clustered randomised controlled trial. *Inj Prev.* 2015:injuryprev-2015.
35. Gabbe BJ, Branson R, Bennell KL. A pilot randomised controlled trial of eccentric exercise to prevent hamstring injuries in community-level Australian Football. *J Sci Med Sport.* 2006;9(1-2):103-9.
36. Hides JA, Stanton WR. Can motor control training lower the risk of injury for professional Football players? *Med Sci Sports Exerc.* 2014;46(4):762-68.

37. Scase E, Cook J, Makdissi M, Gabbe B, Shuck I. Teaching landing skills in elite junior Australian football: evaluation of an injury prevention strategy. *Br J Sports Med.* 2006;40(10):834-38.

APPENDICES

Appendix I

Exercise	Aim of Exercise	Illustration
<p>Shuttle runs: Measure out a distance of approximately 6 m with 1 m interval markings. Running at three-quarter pace, run six shuttles (there and back), progressing each new shuttle by 1 m to a maximum of 6 m for the last return shuttle run. Alternate your turning foot at each end of each shuttle. Maximum distance covered = 42 m per set. Perform two sets.</p>	<p>Hip, knee and ankle stability</p>	 <p>1. THE 'SIX'-METER SHUTTLE-RUN (BENEFITS FOR DYNAMIC HIP, ANKLE AND KNEE STABILITY)</p> <p>Measure out a distance of approximately 6 m, with 1 m interval markings. Running at three-quarter pace, run 6 shuttles (there and back), progressing each new shuttle by 1 m to a maximum of 6 m for the last return shuttle run. Alternate your turning foot at each end of each shuttle. Maximum distance covered = 42 m per set. Perform two sets, before moving onto the next exercise.</p>
<p>Multi-directional lunges: Starting in the middle, with hands on hips, and leading with your left foot, lunge towards the L1 position, drop down and hold this position briefly, then push back to the start. Next, lunge to the L2 position drop down and hold briefly then push back. Continue this pattern up to the L6 position with the left foot leading. Keep shoulders and hips square to the front. Once completed with the left foot, then lead with the right foot, and follow the R1 – R6 movement pattern. Keep the back foot or non-leading foot planted or fixed throughout.</p>	<p>Hip, pelvis, knee and ankle strength and stability</p>	 <p>2. THE 'SIX'-POINT LUNGE (BENEFITS FOR HIP, PELVIS, KNEE AND ANKLE, STRENGTH AND STABILITY)</p> <p>Starting in the middle, with hands on hips, and leading with your left foot, lunge towards the L1 position, drop down and hold this position briefly, then push back to the start. Next, lunge to the L2 position, drop down, hold briefly then push back. Continue this pattern up to the L6 position with the left foot leading. Keep shoulders and hips square to the front. Once completed with the left foot, then lead with the right foot, and follow the R1 – R6 movement pattern. Keep the back foot or non-leading foot planted or fixed throughout</p>
<p>Nordic hamstring curls: Get into the kneeling position with arms folded across the chest. Have a partner hold your lower legs in place by applying downward pressure to your ankles. Tighten your glutes and hamstrings and do not bend forward in the hips. Keeping your back stiff and straight throughout, gradually lean forward and resist the falling down movement as long as possible. When you can no longer resist your fall, catch yourself and fall down into a press-up position. Push yourself back up to where you can tighten the hamstrings and glutes to actively lift and bring yourself back to the start position. Repeat six times.</p>	<p>Glutes, lower back, hamstrings and core strength and stability</p>	 <p>3. THE BUTT-SMART 'SIX' (BENEFITS FOR GLUTES, LOWER BACK, HAMSTRINGS AND CORE, STRENGTH AND STABILITY)</p> <p>Get into a kneeling position with arms folded across the chest. Have a partner hold your lower legs in place by applying downward pressure onto your ankles. Tighten your Glutes and Hamstrings and do not bend forward in the hips. Keeping your back stiff and straight throughout, gradually lean forward and resist the falling down movement as long as possible. When you can no longer resist your fall, catch yourself, and fall down into a press-up position. Push yourself back up to where you can tighten the Hamstrings and Glutes to actively lift and bring yourself back to the start position. Repeat six times.</p>

<p>Push-up with rotation:</p> <p>Complete a push-up with the hands placed slightly wider than the shoulders. Maintain a straight body without arching or bending in the lower back. At the end of the push-up, balance on one arm, twist and rotate the upper-body and leading arm slowly away from the supported side with the hand pointing towards the sky. Alternate between left and right sides. Perform twelve reps, six on each side.</p>	<p>Shoulder, spine control and core strength and stability</p>	<p>4. THE 'SIX'-ON-A-SIDE PUSH-UP AND TWIST (BENEFITS FOR SHOULDER, SPINAL CONTROL AND CORE, STRENGTH AND STABILITY)</p> <p>Complete a push-up with the hands placed slightly wider than the shoulders. Maintain a straight body without arching or bending in the lower back. At the end of the push-up, balance on one arm, twist and rotate the upper-body and leading arm slowly away from the supported side with the hand pointing towards the sky. Alternate between left and right sides. Perform 12 reps, 6 on each side.</p> 
<p>Lunge (with knee lift):</p> <p>Stand upright with the hands held behind the head. With your hips level and back straight, lunge forward with the left leg. At the end of the lunge, push up with the front left leg, and bring your back right leg through while lifting the right knee. Hold this position briefly and with control, reverse the movement back to the start. Alternate between left and right leading legs. Perform twelve reps, six on each leg.</p>	<p>Hip, pelvis, knee and ankle strength and stability</p>	<p>5. THE 'SIX'-BOK LUNGE (BENEFITS FOR HIP, PELVIS, KNEE AND ANKLE, STRENGTH AND STABILITY)</p> <p>Stand upright with the hands held behind the head. With your hips level and back straight, lunge forward with the left leg. At the end of the lunge, push up with the front left leg, and bring your back right leg through while lifting the right knee. Hold this position briefly and with control, reverse the movement back to the start. Alternate between left and right leading legs. Perform 12 reps, 6 on each leg.</p> 
<p>Dynamic reaches:</p> <p>Balance on the left leg while keeping this left leg slightly bent at the knee. Lean slowly forward, reaching as far as you can with both arms and not losing balance, chest facing the ground at all times. At the same time as leaning forward, lift the back right leg to form a straight line with the upper body, while keeping the hips square to the ground. Hold the position for six seconds. Alternate left and right legs between reps. Perform six reps, three on each side.</p>	<p>Shoulder, hip, spine, pelvis, lower back, knee and ankle stability, balance and control</p>	<p>6. 'SIX' DYNAMIC REACHES (BENEFITS FOR SHOULDER, HIP, SPINE, PELVIS, LOWER BACK, KNEE AND ANKLE, STABILITY, BALANCE AND CONTROL)</p> <p>Balance on the left leg while keeping this left leg slightly bent at the knee. Lean slowly forward, reaching as far as you can with both arms and not losing balance; chest facing the ground at all times. At the same time as leaning forward, lift the back right leg up to form a straight line with the upper body, while keeping the hips square to the ground. Hold this position for six seconds. Alternate left and right legs between reps. Perform 6 reps, 3 on each side.</p> 

BokSmart
National Rugby Safety Programme
YOUTH WEEKS INJURY SURVEILLANCE DATA CAPTURE FORM





1. PERSONAL DETAILS

Surname:	Date of birth (dd/mm/yyyy):		
Full names:	Date of injury (dd/mm/yyyy):		
Known as (nickname):	I.D. Number:		
	Gender:		
Height (cm):	Weight (kg):	Age (yrs/months):	
Club/school/team name:			
Provincial Union:	Estimated Date of Return from injury (dd/mm/yyyy):		
Do you have medical insurance?	Number of days missed due to injury:		
Did the player consult with a medical professional regarding their injury?			
<p><i>I understand that the information obtained from the injury report will be treated confidentially with my right to privacy assured. I also understand that should the information be used for a statistical analysis or a scientific report, my identity will not be disclosed in the report.</i></p>			
Player signature	Date:		

Team	Age Group	Pitch conditions	Weather conditions*	Mechanism of injury	Type of injury
School Club	Junior (<U13)	Option1: Soft	Hot	Acceleration	Concussion
U16 Elite squad	U13	Firm	Dry	Bitten	Spinal cord injury
U17 Elite squad	U14	Hard	Light rain	Cleaved	Broken bones/fracture
U18 Elite squad	U15	Very hard	Heavy rain	Cleaning	Joint injury
U19 Elite squad	U16	Option2:	Overcast	Collapsed scrum	Ligament sprain
Grant Komo week U16 squad	U17	Option2:	Cold	Collision	Muscle strain
Craven week U13 squad	U18	Even	Windy	Deceleration	Muscle cramp
Craven week U18 squad	U19	Uneven	Other	Double tackle (high)	Tendon injury
Academy week U18 squad	U20	Option3:	Body location	Double tackle (regulation)	Bruise/contusion
SA U18 Academy squad	U21	Muddy	Head/force (elaborate)	Elbowed	Skin abrasion
SA Schools U18 squad	U23	Slippery		Gauged	Laceration
Provincial U19 squad	Senior	Option4:		Head butt	Other injury
Provincial U20 squad	Position	Medium grip		Jumping	Unsure/do not know
Provincial U21 squad	1 - Loose head prop	Solid footing		Kicked	Nature of injury
SA U19 squad	2 - Hooker	Where injury occurred		Landing	New injury
SA U20 squad	3 - Tight head prop	Warm-up		Lunge	Old or previous injury
SA U21 squad	4 - Lock	Cool-down		Not supported	Protective gear*
SA U23 squad	5 - Lock	Match		Other	Mouth guard
Provincial amateur squad	6 - Open side flank	Weight training		Popped scrum	Shoulder pads
SA Amateur squad	7 - Blind side flank	Fitness conditioning		Punched	Headgear
Emerging Bolts	8 - 8th man	Rugby skills (non-contact)		Rucked	Shin-pads
SA (A) squad	9 - Scrum/inside half	Rugby skills (semi-contact)		Scrum engagement	Strapping
Springboaks	10 - Fly/outside half	Rugby skills (full-contact)		Sideslip	Other
Emerging Women's 7's squad	11 - Left wing	Other		Slipped	Injury definition
Women's provincial U20 squad	12 - Inside center	Time in match when injury occurred		Tackled from behind (high)	Time loss injury
Women's provincial seniors	13 - Outside center	Warm-up		Tackled from behind (regulation)	Medical attention injury
Women's Bolt squad	14 - Right wing	1st Quarter		Tackled front-on (high)	Estimated severity
Provincial 7's squad	15 - Full back	2nd Quarter		Tackled side-on (high)	Slight (0-1 day missed)
Emerging 7's squad	No. of years at this position	3rd Quarter		Tackled side-on (regulation)	Minimal (2-3 days missed)
National 7's squad	0-1yr	4th Quarter		Tackling from behind (high)	Mild (4-7 days missed)
League	1-2yrs	Cool-down		Tackling from behind (regulation)	Moderate (8-28 days missed)
Super League A	2-4yrs	Post-injury decision		Tackling from behind (regulation)	Severe (>28 days missed)
Super League B	5-10yrs	Continued		Tackling front-on (high)	Carer-ending
Premier League A	>10yrs	Discontinued, forced		Tackling side-on (high)	Non-fatal catastrophic
Premier League B	>20yrs	Discontinued, precautionary		Tackling side-on (high)	Fatal
Division 1	Game status within team	Discontinued, blood		Was the injury a result of foul play?	Did the referee take any action?
Division 2	Started match	Stage of season		Yes/No	Yes/No
Division 3	Substitution	Off-season		Elaborate:	
Division 4	Pitch type	Preseason		Running	
Division 5	Grass	In-season			
Division 6	Synthetic				
Division 7	Sand				
Division 8	Gravel				
Division 9	Other				

INSTRUCTIONS FOR USE: Circle the relevant answer in each section. For "Pitch Conditions", circle one selection under each "Option" provided. Under "Injury Definition" the following definitions should be used: A "Time-loss injury" is defined as an injury that results in more than one (1) day absence from training and/or match play. A "Medical attention injury" is defined as an injury that simply requires medical attention.

Appendix IV

 UNIVERSITY OF CAPE TOWN <small>UNIVERSITEIT VAN KAAPSTAD – UNIVERSITEIT VAN SUID-AFRIKA</small>	FACULTY OF HEALTH SCIENCES Human Research Ethics Committee	
---	--	---

17 NOV 2017 HEALTH SCIENCES FACULTY UNIVERSITY OF CAPE TOWN

FHS017: Annual Progress Report / Renewal

Record Reviews/Audits/Collection of Biological Specimens/Repositories/Databases/Registries

HREC office use only (FWA00001637; IRS00001938)			
This serves as notification of annual approval, including any documentation described below.			
<input checked="" type="checkbox"/> Approved	Annual progress report	Approved until/next renewal date	30.11.2018
<input type="checkbox"/> Not approved	See attached comments		
Signature Chairperson of the HREC	Signature removed	Date Signed	19/4/2018

Principal Investigator to complete the following: *Data made to PreCap approval*

1. Protocol information

Date (when submitting this form)	15 November, 2017		
HREC REF Number	438/2011	Current Ethics Approval was granted until	30/10/2016
Protocol title	SARU BokSmart database		
Principal Investigator	Professor M.J. Lambert		
Department / Office Internal Mail Address	Division of Exercise Science and Sports Medicine, Department of Human Biology, Sports Science Institute of South Africa		
1.1 Does this protocol receive US Federal funding?	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No	

2. Protocol status (tick ✓)

<input checked="" type="checkbox"/>	Research-related activities are ongoing
<input type="checkbox"/>	Data collection is complete, data analysis only
Please indicate (in the block below) the titles and HREC reference numbers of any projects currently making use of the Database/registry/repository.	

3. Protocol summary

Total number of records or specimens collected, reviewed or stored since the original approval	N/A
Total number of records or specimens collected, reviewed or stored since last progress report	
Have any research-related outputs (e.g. publications, abstracts, conference presentations) resulted from this research? If yes, please list and attach with this report.	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No



List of publications

Dacotosta, M., Peltzer, E. A. L. M., Van Mechelen, W., Lambert, M. I., Viljoen, W., Readhead, C., et al. (2017). A comparison of catastrophic injury incidence rates by Provincial Rugby Union in South Africa. *Journal of Science and Medicine in Sport*. <http://doi.org/10.1016/j.jsams.2017.01.238>

Burger, N., Lambert, M. I., Viljoen, W., Brown, J. C., Readhead, C., & Hendricks, S. (2016). Tackle technique and tackle-related injuries in high-level South African Rugby Union under-18 players: reel-match video analysis. *British Journal of Sports Medicine*, 50(15), 832–838. <http://doi.org/10.1136/bjsports-2015-095295>

Hendricks, S., O'wenner, S., Lambert, M., Brown, J. C., Burger, N., Mc Fie, S., et al. (2016). Video analysis of concussion injury mechanism in under-18 rugby. *BMJ Open Sport & Exercise Medicine*, 2(1), e000053. <http://doi.org/10.1136/bmjsem-2015-000053>

Mc Fie, S., Brown, J., Hendricks, S., Poethumus, M., Readhead, C., Lambert, M., et al. (2016). Incidence and Factors Associated With Concussion injuries at the 2011 to 2014 South African Rugby Union Youth Week Tournaments. *Clinical Journal of Sport Medicine*, 20(3), 388–404. <http://doi.org/10.1087/JCSM.0000000000000278>

4. Signature

Signature of PI	Signature removed	Date	15 November, 2017
-----------------	-------------------	------	-------------------



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



Room E52-24 Old Main Building
Groote Schuur Hospital
Observatory 7925
Telephone (021) 404 7662 • Facsimile (021) 406 6481
Email: ngs@csmed@uct.ac.za
Website: www.health.uct.ac.za/fhs/research/humanethics/forms

15 February 2017

HREC REF: 108/2017

Prof M Lambert
Human Biology
Exercise Science & Sports Medicine
Sports Science Institute

Dear Prof Lambert

PROJECT TITLE: PLAYERS' AND COACHES' KNOWLEDGE AND AWARENESS OF THE BOKSMART SAFE SIX DURING THE 2014-2016 SARU YOUTH WEEK TOURNAMENTS (PhD-candidate N Sewry)-sub-study linked to 438/2011)

Thank you for submitting your study to the Faculty of Health Sciences Human Research Ethics Committee 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 28th February 2018.

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 Nicola Sewry will be involved in this study.

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

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.

Yours sincerely

Signature removed to avoid exposure online

PROFESSOR M BLOCKMAN
CHAIRPERSON, FHS HUMAN RESEARCH ETHICS COMMITTEE
Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938

HREC 108/2017

Appendix VI



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



Room 853-48 Old Main Building
Groote Schuur Hospital
Observatory 7925
Telephone (021) 406 6626
Email: shuretta.thomas@uct.ac.za
Website: www.health.uct.ac.za/fhs/research/humanethics/forms

04 July 2016

HREC REF: 291/2016

Prof ML Lambert
Sport Science Institute
Human Biology

Dear Prof Lambert

PROJECT TITLE: THE BOKSMART SAFE SIX INJURY PREVENTION PROGRAM: A PILOT STUDY (SUB-STUDY LINKED TO 850/2015) PHD CANDIDATE MS N SEWRY)

Thank you for your response to the Faculty of Health Sciences Human Research Ethics Committee dated 27 June 2016.

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 30th July 2017.

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)

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 before the research may occur.

The HREC acknowledge that the student, Beatrice du Toit will also be involved in this study.

Yours sincerely

Signature removed to avoid exposure online

PROFESSOR M/BLOCKMAN
CHAIRPERSON, FHS HUMAN RESEARCH ETHICS COMMITTEE

Federal Wide Assurance Number: FWA00001637.

Institutional Review Board (IRB) number: IRB00001938

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

HREC REF 291/2016



UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
HUMAN RESEARCH ETHICS COMMITTEE



Room E52-24 Old Main Building
Groote Schuur Hospital
Observatory 7925
Telephone: [021] 406 6338 + Facsimile [021] 406 6411
Email: hrc@fhs.uct.ac.za
Website: www.health.uct.ac.za/fhs/research/humanethics/forms

11 March 2016

HREC REF: 850/2015

Prof M Lambert
Human Biology
Sports Science Institute

Dear Prof Lambert

PROJECT TITLE: THE IMPLEMENTATION OF THE BOKSMART SAFE SIX INJURY INTERVENTION PROGRAM: A CLUSTER RANDOMISED CONTROL TRIAL (PhD-candidate- Ms N Sewry)

Thank you for your response letter to the Faculty of Health Sciences Human Research Ethics Committee dated 07 March 2016.

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

Approval is granted for one year until 30 March 2017.

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, Nicola Sewry 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.

Yours sincerely

Signature removed to avoid exposure online

PROFESSOR H BLOCKMAN
CHAIRPERSON, FHS HUMAN RESEARCH ETHICS COMMITTEE

Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938

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

HREC 029/2015

Appendix VIII

Audrey.wyngaard@westerncape.gov.za

tel: +27 021 467 9272

Fax: 0865902282

Private Bag x9114, Cape Town, 8000

wced.wcape.gov.za

REFERENCE: 20160712 – 2283

ENQUIRIES: Dr A T Wyngaard

Ms Nicola Sewry
1101 Salwood Court
Arbor Road
Newlands
7700

Dear Ms Nicola Sewry

RESEARCH PROPOSAL: THE IMPLEMENTATION OF THE BOKSMART SAFE SIX INJURY PREVENTION PROGRAM: A CLUSTER RANDOMISED CONTROL TRIAL

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Educators' programmes are not to be interrupted.
5. The Study is to be conducted from **01 March 2017 till 30 August 2017**
6. No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December).
7. Should you wish to extend the period of your survey, please contact Dr A.T Wyngaard at the contact numbers above quoting the reference number?
8. A photocopy of this letter is submitted to the principal where the intended research is to be conducted.
9. Your research will be limited to the list of schools as forwarded to the Western Cape Education Department.
10. A brief summary of the content, findings and recommendations is provided to the Director: Research Services.
11. The Department receives a copy of the completed report/dissertation/thesis addressed to:

The Director: Research Services

**Western Cape Education Department
Private Bag X9114
CAPE TOWN
8000**

We wish you success in your research.

Kind regards.

Signed: Dr Audrey T Wyngaard

Directorate: Research

DATE: 13 July 2016