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Shoulder Injury Risk and Injury Prevention in Rugby Union Players

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Shoulder Injury Risk and Injury Prevention in Rugby Union Players

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Abstract

Shoulder injuries are amongst the most common rugby injuries across all playing levels and accounts for a significant injury burden. The purpose of this dissertation was to investigate strategies that might reduce the risk of shoulder injuries in rugby union players.

Study one found that semi-professional players sustained a greater incidence of injuries (2.8 per 1000 hours, 95% CI: 2.2 to 3.5) than recreational players (1.8 per 1000 hours, CI: 1.4 to 2.2, p=0.004) in adult community rugby players. Tackling caused the highest proportion of injuries and shoulder sprain and dislocation and acromioclavicular injuries were the most common injury types. The highest incidence for all shoulder injuries was reported for back row players (2.9 per 1000 hours, CI: 2.2 to 3.6).

Study two showed that observational evaluation of rugby players' shoulder girdles by novice and experienced raters has poor to moderate reliability. These findings do not support the use of visual observational tests to determine the orientation of the scapula and clavicle, bringing into question the use of these tests in clinical practice.

Importantly, study three outlined the development process of an evidence-based shoulder-specific injury prevention programme for community youth rugby players using input from a multidisciplinary technical project group, feedback from stakeholders and end users. The fourth study was a pilot study that identified meaningful findings about the vital role of the coach as the delivery agent of preventive programmes at this playing level and the need to address negative perceptions about injury prevention was identified. In addition to this, collecting self-reported injury data using SMS is considered a viable option in this setting.

The final study was a pre-experimental study showing outcome measures that were able to detect change after using a lycra compression sleeve in active shoulder external rotation range, passive shoulder internal rotation range and there were some positive trends seen on the acromion-greater tuberosity distance and shoulder laxity outcomes.

Declaration of work done in conjunction with others

Publications

Singh, V., Trewartha, G., Roberts, S., England, M., & Stokes, K. (2016) Shoulder injuries in English community rugby union. *International Journal of Sports Medicine, 37*(08), 659-664.

Conference presentations

Singh R.V., Trewartha G., Stokes K., McKay C. (2017) The reliability of the scapula posture and scapula dyskinesis tests in rugby union players. *World Confederation for Physical Therapy Congress 2017.* Cape Town, South Africa.

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Chapter One

Introduction

Rugby union is a team sport that has a number of variations, such as touch rugby, Rugby 7s, Rugby 10s, rugby league and rugby union. The focus of this thesis will be on the 15-a-side variant of rugby union (hereafter 'rugby'). In 1995, rugby became a professional sport, which sparked a rise in its popularity. Recent figures suggest that rugby is played in 121 countries and has 8.5 million players (World Rugby Year in Review 2016), 2.2 million of whom are female players. More than a third of the playing population are under the age of 18 years. The largest playing population in the world is in England, with over 2 million athletes and 856 community clubs.

Rugby is a sport that offers an opportunity to promote physical activity for children and adults, reducing the risk of developing hypokinetic diseases such as obesity, diabetes and heart disease (Blair 2009, Matheson, Klügl, Engebretsen et al. 2013). Sport participation is not without the risk of sustaining an injury, which is the leading reason why people discontinue participating in physical activity (MacKay, Scanlan, Olsen et al. 2004). Therefore, limiting the risk of injury through effective injury prevention strategies may increase the likelihood of benefits associated with physical activity. All those involved in rugby have a responsibility to improve player welfare by contributing to the development of evidence-based strategies to reduce the risk of injury at all levels of the game.

There are several sport injury prevention frameworks that exist, namely the "Sequence of Prevention" (van Mechelen, Hlobil and Kemper 1992) and the more recent "Translating Research Into Prevention Practice" (TRIPP) (Finch 2006). The first step of the process involves determining the magnitude of the injury problem through sports injury surveillance research. This is followed by investigations to identify the aetiological factors contributing to those injuries. There have been numerous epidemiological studies which have started to develop longitudinal player injury tracking at elite and community level rugby (Bathgate, Best, Craig et al. 2002, Fuller, Sheerin and Targett 2012, Roberts, Trewartha, England et al. 2013). Currently, extensive high quality data is lacking for adolescent rugby union (Bleakley, Tully and O'Connor 2011). The lack of resources at lower playing levels and particularly amongst community youth, impedes injury surveillance (Gabbe, Finch, Wajswelner et al. 2003) and is further hindered by considerable variation in surveillance methodology (Brooks and Fuller 2006, Clarsen and Bahr 2014), rendering data incomparable between studies using different methodologies. Standardisation of injury surveillance methods and systems that are reliable, valid and represent the target audience may allow for a degree of homogeneity in comparing injury data (Ekegren, Donaldson, Gabbe et al. 2014). The consensus statement on injury definitions and injury surveillance in rugby union is proposed to address the methodological issues in this area (Fuller, Molloy, Bagate et al. 2007). Pursuing injury surveillance research in youth rugby would provide new knowledge that may contribute to a better understanding about the barriers to injury reporting at this playing level.

To date, emphasis in the rugby research community has largely been on injury surveillance addressing high risk injuries, such as catastrophic injury or those that carry a high injury burden. Injuries to the spinal cord, those that affect the stability of the knee, and concussion have received much of this focus (Fuller 2008, Cazzola, Preatoni, Stokes et al. 2014, Preatoni, Cazzola, Stokes et al. 2016). Notably, studies also show that upper limb injuries are a significant problem, accounting for 14% - 28% of all rugby injuries (Usman and McIntosh 2013). Shoulder injuries in particular contribute to some of the highest injury burden in professional players (Headey, Brooks and Kemp 2007), with similar findings at junior levels (Haseler, Carmont and England 2010, Palmer-Green, Stokes, Fuller et al. 2013). Data from across junior leagues shows that the shoulder was the most common injury location in the U20 Rugby World Cup (Fuller, Taylor and Raftery 2018), and was found to be the second most frequent injury location and had the greatest injury burden for any specific body location in elite U17 schoolboys' rugby in England (Barden and Stokes 2018). Shoulder and knee injuries also had the highest reported incidence in community youth rugby (Haseler, Carmont and England 2010). The injury data presented here is irregularly dispersed over discontinuous playing seasons which accounts for the fact that injury surveillance at youth playing levels requires further development. Injuries to junior players during a time when major physiological developments are occurring can have considerable consequences (Caine, DiFiori and Maffulli 2006, Maffulli, Longo, Spiezia et al. 2010). Therefore, injury prevention must be prioritised within junior sport to decrease the risk of injury recurrences, prevent the development of long-term musculoskeletal conditions and to encourage a physically active lifestyle across the lifespan (Hamilton, Maclean and Simpson 2015).

Following on from epidemiological enquiry, modifiable injury risk factors should be identified which can be used to inform the development of appropriate preventive interventions. Injury risk factor screening of intrinsic factors is used to support clinical judgement and offers an opportunity to intervene with players who have traits that increase their likelihood of sustaining an injury (Verhagen, van Dyk, Clark et al. 2018).

Glenohumeral laxity and instability, reduced shoulder external rotation strength (Stewart and Burden 2004, Cheng, Sivardeen, Wallace et al. 2012, Ogaki, Takemura, Iwai et al. 2014), and shoulder range of motion deficits (Fernandez, Aravena, Verdugo et al. 2011) are a few risk factors that have been shown to be associated with shoulder injuries in rugby players. There is a conflicting body of evidence regarding the causal relationship of scapular impairment and shoulder conditions (Kawasaki, Yamakawa, Kaketa et al. 2012, Cools, Struyf, De Mey et al. 2014, Struyf, Nijs, Mottram et al. 2014), leaving the issue still up for debate. Nevertheless, identifying aetiological risk factors relies on the accuracy of the test that is being used and the rater's level of experience (Moller, Attermann, Myklebust et al. 2018). Establishing the reliability of musculoskeletal assessments used to evaluate the shoulder girdle (scapula and clavicle) is fundamental in providing clinicians with information to determine whether these tests are useful in clinical practice (Wright, Wassinger, Frank et al. 2013).

Informed by the findings from descriptive and analytical investigations in rugby injury research, preventive interventions can then be considered. There are a number of interventions that may be used to prevent sport injuries. The most noteworthy prevention strategies in rugby have targeted catastrophic injuries to the head and spinal cord by improving coaching standards and making amendments to the law of the game (Quarrie, Gianotti, Hopkins et al. 2007, Gianotti, Quarrie and Hume 2009, Cazzola, Preatoni, Stokes et al. 2014, Patricios 2014, Brown, Verhagen, Knol et al. 2016). These initiatives are mainly targeted at reducing the risk of injury during contact phases such as the tackle and scrum, which threaten the injured player's subsequent welfare. Interventions used in other sports, such as neuromuscular training as part of a warm up routine, have shown to be efficacious in preventing less severe although more frequent musculoskeletal injuries (Emery, Roy, Whittaker et al. 2015, Thorborg, Krommes, Esteve et al. 2017) and a few attempts have been made to reduce shoulder injuries in overhead sport (Andersson, Bahr, Clarsen et al. 2017). Similar interventions introduced in schoolboy and adult community rugby to reduce the incidence and burden of rugby-related injuries have shown significant injury reductions (Hislop, Stokes, Williams et al. 2017, Attwood, Roberts, Trewartha et al. 2018).

Notably, schoolboy teams with high intervention compliance (teams completing the intervention at least three times a week) to a preventive exercise programme sustained 43% fewer overall match injuries than intermediate compliance teams (incidence relative risk (RR)= 0.57, 90% confidence limit 0.38-0.85) (Hislop, Stokes, Williams et al. 2017). Moreover, a likely beneficial reduction of 50% in targeted injury burden was seen when comparing higher compliance to lower compliance (≥85% to <85% of possible sessions) adult community rugby teams (Attwood, Roberts, Trewartha et al.

2018). Neuromuscular training programmes suffer from poor compliance across all sports (Soligard, Nilstad, Steffen et al. 2010, Finch, Diamantopoulou, Twomey et al. 2014), and based on these studies, there is a need to investigate strategies to maximise programme uptake among rugby players as well.

There is, however, no "one size fits all" strategy for injury prevention, and what works in one context may not work in another. The contexts of both these studies (Hislop, Stokes, Williams et al. 2017, Attwood, Roberts, Trewartha et al. 2018) in rugby may not be equivalent at all playing levels, such as in community youth rugby. The teams involved in the Hislop et al. (2017) study were all students at independent schools who had an on-site physiotherapist or nurse to treat all rugby related injuries while in the adult community study, clubs had access to a registered healthcare professional for injury diagnosis (Attwood, Roberts, Trewartha et al. 2018). Community youth clubs do not have the advantage of such resources, which poses a significant challenge to injury surveillance and preventive endeavours. To date, it has been difficult to develop effective injury prevention strategies in community rugby where injury surveillance is not mandatory. Trialling a bespoke injury surveillance system alongside a shoulder-specific injury prevention intervention in this setting will allow for important barriers and facilitators to adoption and sustainability to the intervention to be understood. A recognised knowledge gap in all sport injury prevention research identifies that there is little known about the reasons for the uptake or lack of adoption to an intervention with studies merely stating that the intervention did or did not work (Donaldson and Finch 2013, O'Brien and Finch 2014, O'Brien, Donaldson and Finch 2016). Consideration also needs to be given to the individual safety behaviour that influences adoption such as the form of delivery, who delivers the intervention and the social and physical environments in which they operate (Finch 2006). Individuals are influenced by the groups they belong to, and in the community youth rugby setting it is important to understand the influence that the coach may have on the adoption of the implemented intervention.

In addition to training programmes, research initiatives to minimise the risk of injury to players in sport have also explored equipment-based interventions (McBain, Shrier, Shultz et al. 2012). Considering the effects of repeated impacts to the shoulder during rugby such as aberrant muscle activity of the rotator cuff muscles (Herrington and Horsley 2009, Faria, Campos and Jorge 2017) and sensorimotor system deficits (Herrington, Horsley, Whitaker et al. 2008, Morgan and Herrington 2014) which jeopardise the stability of the shoulder, there is scope to investigate whether joint stabilisers may reduce these deleterious consequences. Positive effects have been seen on shoulder laxity in healthy people (Kumar, Desai and Elliot 2019) and those with neurological conditions (Kumar 2019) when using a lycra compression sleeve. In rugby, shoulder instability and dislocation poses a significant injury burden which warrants trialling such a sleeve to offer researchers and clinicians evidence to guide its use in practice.

Aims

Therefore, the aims of this research were to reduce the risk of shoulder injuries in youth rugby union players through a process of establishing injury patterns, evaluating the reliability of tests used to identify risk factors, and trialling two injury prevention interventions.

The following research questions will be addressed in this thesis:

i.) What is the incidence, severity and type of shoulder injuries resulting from match play in community rugby?

ii.) Determine the reliability of assessing the scapula by novice clinicians, and what is the contribution of these tests in the clinical reasoning process applied in the prevention and management of shoulder complaints in rugby union players?

iii.) How do you develop an implementable shoulder-specific injury prevention exercise programme for community youth rugby players?

iv.) What is the feasibility and acceptability of a shoulder-specific injury prevention exercise programme in community youth rugby?

v.) What is the feasibility of a self-reported injury registration method using SMS alongside a shoulder-specific injury prevention exercise programme in community youth rugby?

vi.) Does wearing a lycra compression sleeve outside of rugby confer structural or functional benefits to rugby union players' shoulders when the sleeve is removed from use?

Thesis outline

Chapter 2: Literature review

The objectives of this chapter is to outline the significance of shoulder injuries, their causation, and existing preventive measures investigated in rugby. The importance of sport injury research is briefly introduced to provide a basis for the specific literature relevant to this topic and a contextual background for the experimental chapters of this thesis. A review of the current body of evidence pertaining to shoulder injuries in rugby, with particular attention to youth players, is presented.

Chapter 3: Shoulder injuries in English community rugby players

A secondary analysis of the epidemiology of shoulder injuries in adult community rugby is presented in this chapter, providing a data set for comparison with the youth population. The injury rate, severity and mechanism of injury are reported from data extracted from the Community Rugby Injury Surveillance Project from 2009-2013, which involved adult community rugby players in England. The possible risk factors for these injuries are also reported and discussed.

Chapter 4: Reliability of scapular and clavicular tests in rugby players

The ability to identify injury risk factors is partly dependant on the reliability of the investigations used to assess these outcome measures. The aim of this study was to assess the inter-rater and intra-rater reliability of scapula and clavicular assessments in rugby players between expert and novice raters. The findings are discussed in relation to the extent to which the tests may be reliably used by clinicians and researchers working with rugby players.

Chapter 5: Development of a shoulder-specific warm up programme to prevent shoulder injuries in community youth rugby

This chapter outlines the development process of a shoulder-specific warm up programme that aimed to reduce the frequency of injuries in a community youth rugby population. It focuses on the steps that were followed to create the structure and content of the warm up routine, considering the delivery strategy and implementation context of the intervention.

Chapter 6: Effectiveness of a shoulder-specific warm up programme to prevent shoulder injuries in community youth rugby: a pilot study exploring feasibility and proof of concept

The aim of this pilot study was to describe the feasibility and acceptability of the aforementioned shoulder-specific injury prevention warm up routine in community youth rugby clubs. These findings explore whether a warm up programme, designed to reduce shoulder injuries, encourages a cohort of community youth rugby players to adhere to the programme. Coach and player attitudes and beliefs towards injury prevention are also described in this chapter.

Chapter 7: The effects of a lycra compression sleeve on shoulder function in rugby players: a pre-experimental study

The aim of this study was to determine the effect of a lycra compression sleeve on shoulder function, to explore its potential prophylactic and rehabilitative uses in rugby. This investigation described the potential mechanisms by which the sleeve may work.

Chapter 8: General Discussion

In this chapter a summary of the key findings from each chapter is presented. The potential to translate this research into practice and its generalisability is evaluated. Future research directions are also discussed. The practical implications and key findings of this research are summarised to help researchers, clinicians, practitioners, stakeholders and end users to understand shoulder injury risk and injury risk management in youth rugby. *Figure 1* below illustrates the structure of this thesis.

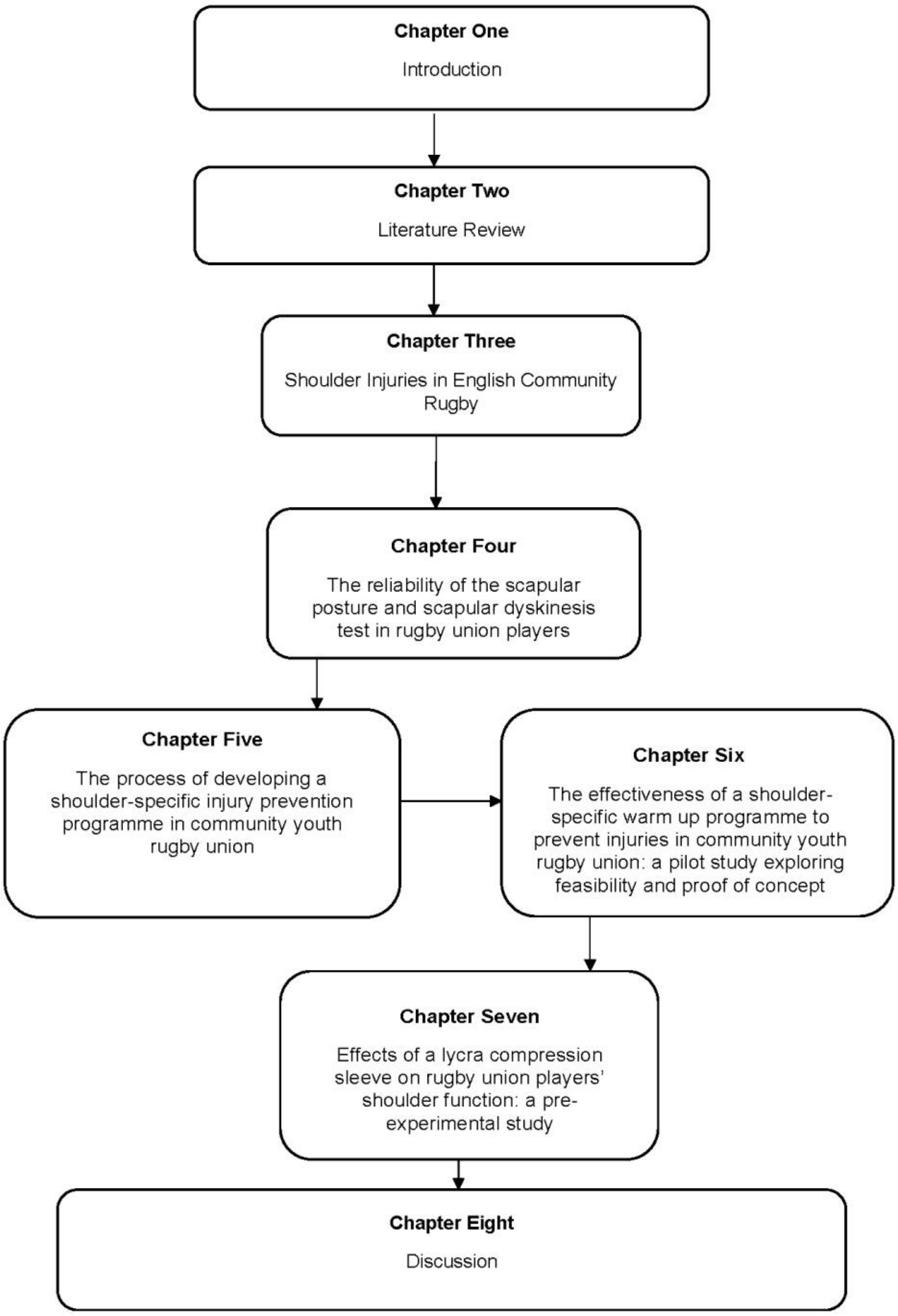

Figure 1: Structure of thesis

Chapter Two

Literature Review

Introduction and background

Sport plays an important role in mobilising the world's population by increasing physical activity levels and thereby combating the deleterious effects caused by a sedentary lifestyle. Conclusive evidence demonstrates that regular participation in physical activity has significant health benefits ranging from reduced risk of heart disease, type 2 diabetes and some cancers (Blair 2009, Lee, Shiroma, Lobelo et al. 2012, Trost, Blair and Khan 2014). Injury is the leading reason why people discontinue physical activity participation; therefore, limiting the associated risk of injury through effective injury prevention strategies may increase the likelihood of benefits associated with physical activity (MacKay et al. 2004). Currently there is considerable interest from academics, medical and public health professionals in understanding the risk of injury involved in sport (Ljungqvist 2008, Engebretsen, Bahr, Cook et al. 2014, Longmuir, Colley, Wherley et al. 2014, Finch, Bahr, Drezner et al. 2017). Sport injury prevention research is consequently an invaluable asset in the fight against physical inactivity to allow us to better understand the risks involved in the sport and enable a strategic approach to try and reduce those modifiable risks.

Rugby union is a popular team sport played in 121 countries with approximately 8.5 million active players. The popularity of rugby has undoubtedly increased by the landmark events in the media that contributed to increased participation rates when the sport entered the professional era in 1995 and when it returned to the 2016 Olympics in the sevens format. These professional tournaments speak for the elite level of the sport, but a large percentage of the rugby playing population is made up by the youth and adolescent age group. In England, they make up a larger proportion of players than any other country. One of the aims of the Rugby Football Union (RFU) is to increase the number of secondary state schools playing rugby union through the 'All Schools' development programme. Since 2012 this programme has been taken to 750 secondary state schools and the RFU aims to create a positive legacy for 1 million children through rugby union and its core values. This is an ambitious intention and it is imperative for the associated risk of the sport to be minimised as much as possible to ensure that children sustain life long participation. Considering the growing participation levels and to support player welfare, World Rugby must continue to prioritise and invest in making the game as safe as possible for players at all levels (World Rugby 2014).

Sport Injury Research

Sport injury prevention research has been developed from the principles and methodologies used in the epidemiology of disease in a population. The initial sport injury prevention framework presented in the Sequence of Injury Prevention (Figure 2) (van Mechelen, Hlobil and Kemper 1992) provided a valuable contribution by describing the magnitude of the problem, in terms of the frequency and severity of sports injuries in step one, and also in attempting to identify the contributing factors to the injury as part of step two. The significant body of evidence that has emerged from using this framework indicates a high level of concern about the impact of sport injuries and a need to address the challenges of translating these concerns into intervention studies to prevent injuries in the real-world (Klugl, Shrier, McBain et al. 2010).

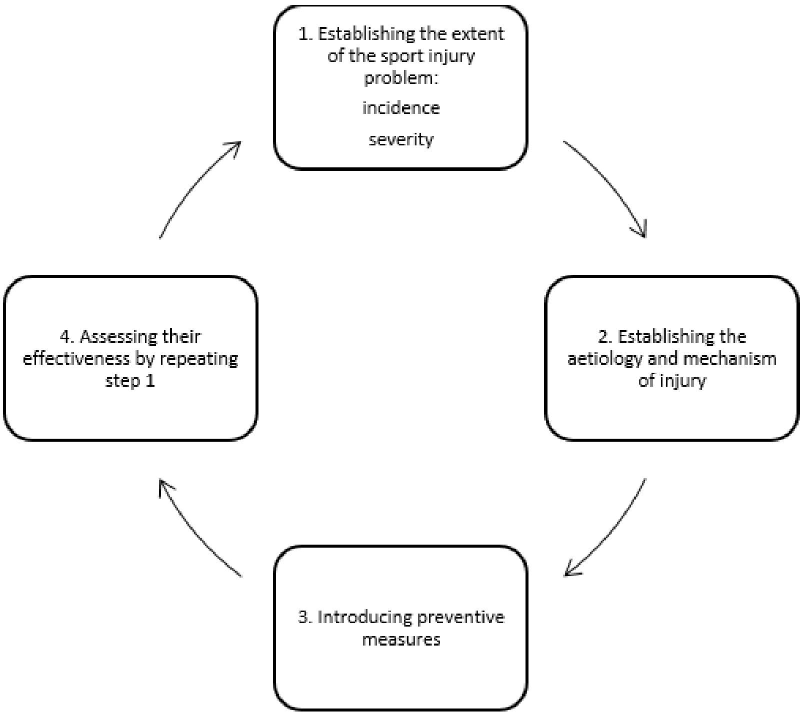

Figure 2: The 'sequence of prevention' of sports injuries (van Mechelen, Hlobil and Kemper 1992)

The Injury risk management framework in sport (Fuller and Drawer 2004) was a successor to the Sequence of Injury Prevention, which recognised that identifying high risk activities is not sufficient to reduce injuries. This framework involves identifying risk factors that might lead to injury and the levels of risk associated to be evaluated. In the first stage, identified intrinsic and extrinsic risk factors are used to categorise the level of risk the athlete is exposed to in the sport. This is followed by attending to the perceptions of risk and levels of risk acceptance among stakeholders prior to deciding if there is a need to introduce preventative measures. Once preventative measures have been implemented and injury reduction has occurred to socially acceptable levels, there is a need to communicate the information of the risk of injury and prevention measures to stakeholders. This framework advanced the previous model by acknowledging that injury prevention will only be successful if it is adopted at multiple levels in sport. A recognised limitation of these models is that they lack consideration of behavioural factors which contribute to the adoption of any intervention.

These models have since been superseded by the Translating Research into Injury Prevention Practice (TRIPP) model (Finch 2006) (Table 1). The TRIPP model overlaps the four stages of the Sequence of Injury Prevention and builds on it by necessitating that research advancements are made to understand the behavioural factors which contribute to the adoption of preventative interventions. It highlights that researchers must realise the implementation context for the multifactorial complex nature of sport injury prevention to lead to real-world injury reduction.

Model Stage	TRIPP
1	Injury Surveillance
2	Establish aetiology and mechanisms of injury
3	Develop preventive measures
4	Ideal conditions/ scientific evaluation
5	Describe intervention context to inform implementation strategies
6	Evaluate effectiveness of preventive measures in implementation context

Table 1: The Translating Research into Prevention Practice (TRIPP) framework (Finch 2006)

The first two steps of the TRIPP model recognises the importance of the need for the evidence base for sport injury prevention along with the causative factors for those injuries before preventative measures can be developed and evaluated in steps three and four. In sport there are numerous different injury reporting methods employed to capture the magnitude of the injury which requires the researcher to be prudent when comparing injury data (Brooks and Fuller 2006). Specifically in rugby, epidemiological research is recommended to follow the injury consensus statement (Fuller, Molloy, Bagate et al. 2007). To highlight, reliable data is central to describing the scale of shoulder injuries in rugby and is crucial in establishing the first stage in the Sequence of Prevention (van Mechelen, Hlobil and Kemper 1992) and the Translating Research into Prevention Practice (TRIPP) model (Finch 2006, Klugl, Shrier, McBain et al. 2010). Injury surveillance permits an understanding of emerging injury patterns and is essential at all levels to inform an evidence-based framework to minimise risk through preventative strategies (Roe, Malone, Blake et al. 2017).

To then understand the aetiology of shoulder injuries in sport, a multidisciplinary approach is required to inform a shared understanding of contributing injury risk factors related to that sport. The expertise of biomechanists and clinicians are important to better understand risk factors with the emerging relevance of sports biostatisticians as critical members of the injury prevention team (Bahr and Krosshaug 2005, Casals and Finch 2017). Conducting analytic epidemiological studies are complex, often require additional resources and are faced with logistical and administrative challenges, which possibly accounts for why there are more descriptive epidemiological studies than analytical epidemiological research (McBain, Shrier, Shultz et al. 2012).

Steps one and two of the TRIPP model contribute to informing the development process of a preventative strategy in step three, which is then evaluated in step four. The subsequent steps of the TRIPP model advance its predecessors by moving beyond efficacy of preventative interventions and towards understanding the facilitators and barriers in the implementation context. Issues of poor compliance and adherence to the prevention programme have been shown to affect the effectiveness of injury prevention exercise programmes in a number of different sports (Steffen, Emery, Romiti et al. 2013, van Reijen, Vriend, van Mechelen et al. 2016). Stages 5 and 6 of the TRIPP model aim to transfer efficacious injury prevention into real-world sport settings (Finch 2011). Each sporting context is different, which requires researchers to develop an understanding of the most appropriate way to design, implement and achieve successful adoption of preventative interventions for that sport and its participants. Transitioning injury prevention efficacy to effectiveness is challenging due to the scarce amount of literature available to guide this process (Finch 2011, Bekker, Paliadelis and Finch 2017). The emerging evidence in this field proposes that injury prevention is collaboratively designed with multiagency input to bridge the gap between research (top-down) and end user (bottom-up), which is driven by the implementation process (Verhagen, Voogt, Bruinsma et al. 2014, Finch, Donaldson, Gabbe et al. 2016). Implementation research in this context involves the development process of population targeted interventions that takes into account the design of components to support the delivery of the intervention and includes evaluating its effectiveness, uptake, adoption and sustainability (Finch 2011).These latter stages of the TRIPP model are underrepresented in the literature and research needs to move beyond the initial stages of these research frameworks.

Injury definition and characteristics

Injury surveillance is central to establishing how big a problem injuries are in sports, and a key component to achieving this outcome is to utilise agreed injury definitions. Agreement about what constitutes an injury has been a long-recognised issue in sports medicine (Meeuwisse and Love 1997). There exists a multitude of sport injury definitions used in a variety of settings, ranging from insurance claims to hospital admissions, each with their own strengths and weaknesses; however, variation in sports injury definition render the results of various studies incomparable (Finch 1997). In collision sports such as rugby union where the potential risk of injury is high, a number of injury definitions have been used. For example, in professional rugby players in New Zealand, injuries reported using a 'missed training and match' definition accounted for overall, 120 injuries per 1000 player hours (n=25) (Targett 1998), while when the 'injured player is removed from the match' definition is used at a higher playing level, the overall injuries were much lower, 32 per 1000 player hours (n= 416, Rugby World Cup 1995) (Jakoet and Noakes 1998). The registration of injuries using these definitions is dependent on the frequency with which matches are played and the former definition that combines training and matches is also influenced by the impact that the injury has on the player training. As a result of this, these different injury definitions contributed to the variability in reported rugby epidemiology data (Brooks and Fuller 2006, Kaplan, Goodwillie, Strauss et al. 2008). Comparable injury definitions was seen when using the definition of an 'injured player leaves the field, misses the next match or both' with overall injuries of 69 per 1000 player hours reported for the Australian Wallabies during 1994 – 2000 (n=82) (Bathgate, Best, Craig et al. 2002), 98 injuries per 1000 player hours in the Rugby World Cup 2003 (Best, McIntosh and Savage 2005). Similar injury rates were reported when the injury resulted in the player not completing the match and resulting in 24 hour time-loss from training or a match with an overall match injury rate of 91 per 1000 player hours (n=546) for professional rugby players (Brooks, Fuller, Kemp et al. 2005).

Consequently, a consensus statement on injury definitions and injury surveillance for rugby union was produced, recognising the importance of an agreed injury definition and methodologies for recording injuries in rugby union (Fuller, Molloy, Bagate et al. 2007). The agreed statement describes "*Any physical complaint"* as an injury that results from the player's body's inability to withstand a transfer of energy during rugby, irrespective of the need for either medical attention or time-loss from rugby activities.

When a player receives medical attention for an injury it is referred to as a 'medical-attention' injury and when a player is unable to participate in training or match-play, it is a 'time-loss' injury. The Orchard Sport Injury Classification System (OSICS) (Rae and Orchard 2007) is used to record injury diagnosis in sport injury epidemiology and is the most commonly used in rugby union (Rae and Orchard 2007). Using the consensus statement and OSICS greatly improves opportunities for making inter-study comparisons of results provided that the cohort have the necessary resources available to them to facilitate injury management staff to record injuries. This is currently the best theoretical definition available and is widely used in rugby union injury epidemiology.

Injury severity was defined in the consensus statement by the number of days a player is absent from training and matches, and is grouped in the following categories: slight (0-1 days), minimal (2-3 days), mild (4-7 days), moderate (8-28 days), severe (>28 days), 'career-ending' and 'non-fatal catastrophic injuries' (Fuller, Molloy, Bagate et al. 2007). A time-loss injury is defined as either an injury that resulted in >24 hours of time loss or a broader definition of at least one missed match (>7 days). This definition assumes that matches are played once a week and is not valid in all settings where match-play is scheduled more or less frequently. These definitions were compared in a large study involving 2248 professional rugby players over 12 seasons in England that reported 86 injuries per 1000 hours using the >24hour definition and 43 injuries per 1000 hours when using the >7day definition (Cross, Williams, Kemp et al. 2018). This study represents a specific playing level of elite senior male rugby population, nonetheless it importantly highlights the degree of variation with the different injury definitions. These findings indicate that 50% of match injuries were not reported using the >7day definition which, if left unreported, would under-represent the injury risk and clinical workload required in the management of these injuries. The less severe injuries (<7days) are important to report as they may affect the players' availability for selection and in the medium to long term, may be a precursor to future injuries. In addition, to better understand the injury problem in rugby, in subsequent studies the injury severity definition has been extended beyond the time away from match play and also includes the nature of the sport injury, duration and nature of treatment, sporting and working (employment) time lost, permanent damage and monetary cost associated with rugby injuries which is often an ignored analysis in research studies (Brown, Viljoen, Lambert et al. 2014).

Injury surveillance definitions are interested in the players' ability to continue training or competing, which reveals that there are a number of confounding factors with this injury definition that should be considered. Firstly, players have varying levels of pain for identical injuries (Hammond, Lilley, Pope et al. 2014) which will be a determining factor for when they return to sport. Following an injury, there are a number of variables that need to be considered in making the return to sport decision and broadly encompasses the clinician's judgement, relevant scientific evidence and patient values (Shrier 2015). All of these return to sport factors will contribute to the varying duration of time loss following identical injuries, thereby influencing the extent of the injury. Other factors that may impact on the injury definition is the issue of 'playing hurt' which has been explored by sociologists who have proposed that there may be deep rooted attitudes and beliefs in a 'culture of risk' that have led players to accept and normalise pain and injury in sport (Liston, Reacher, Smith et al. 2006). The qualitative findings from interviewing rugby players (n=38, university rugby union and league players aged 19 to 23 years old) identified closely held beliefs among players that they should continue to play with pain and injury 'for the good of the team' (Liston, Reacher, Smith et al. 2006). Using consistent operational sport injury definitions in research is regarded as important to increase the level of comparability across studies; however, it is not possible to eliminate all sources of inconsistencies and grey areas associated. These potential injury registration biases may limit an accurate estimation of the magnitude of the problem by under-estimating the overall incidence of injuries in rugby. Researchers needs to consider these implications to provide value to epidemiological studies in sport injury.

The majority of research tends to employ either the time-loss or medical-attention definition when recording injury data, with the former likely to record the fewest incidents though it is assumed that this definition allows for an easy identification of a player's inability to participate in training or a match. This may also allow for a more reliable means of data collection and does not require medically qualified personnel to record the injury. There are limitations to this definition in that players may continue to participate at a lower training volume, thereby working below the threshold of the injury or if the player uses medication to mask their symptoms and therefore the underlying injury is unreported. Injuries that occur at the end of the season may also go unreported as there will not be any training or matches missed. High performing players may have other pressures in that they may be less likely to miss time due to minor injuries during key periods in the competitive season. Previous research using the time-loss injury definition reflect the immediate impact of injuries on players and are at risk of the aforementioned issues resulting in some injuries being unreported. To fully understand the extent of injuries in rugby, there needs to be consideration of those complaints that are not captured by the time-loss or medical-attention injury definitions and an injury surveillance system that does not require the involvement of medical personnel.

Medical attention injuries in rugby are typically not recorded as injuries unless they result in time-loss or contribute to a focused case study report. Similarly, the ‘all complaints’ definition is seldom used, but its strengths and limitations are similar to that for the medical-attention definition. The choice of the injury definition would likely be dependent on the aims and context of the injury surveillance and the type of data sources available. It is also expected that the ‘all complaints’ definition will yield a higher injury rate than ‘medical attention’ definition, and ‘time-loss’ resulting in the lowest rate (Bahr 2009, Clarsen and Bahr 2014). In cases where rugby players with suspected concussion require medical attention, if concussion is excluded, they may return to the field of play. Reporting this injury as a medical attention injury may have important medical consequences and should not be ignored (Viviers 2016). The decision to use this type of injury reporting may also be to assist in understanding the extent of medical resources required for a large-scale sport event. In the absence of medical support structures, this method of injury reporting may result in an increased burden on the overseeing data collector. Nonetheless, injury data in sport where there is high risk of injury is central to quantify that risk. Where injury surveillance personnel are utilised, they may have varying levels of qualifications which can contribute to under-estimation of injury reporting due to the discrepancy in the data collectors’ interpretation of what constitutes an injury (Finch, Orchard, Twomey et al. 2014).

The injury definition conundrum has further complexities in attempting to define overuse injuries, as they do not have a specific identifiable event responsible for their occurrence. Players continue to train or modify their training by refraining from the most aggravating activity in the early stages of the injury and at a later stage will seek medical consultation for the injury (Bahr 2009, Clarsen, Myklebust and Bahr 2013). Attempts from players to avoid time-loss from their sport is accomplished by postponing rest of recovery to the off season, outside of the injury surveillance coverage, as seen in top-level overhead athletes competing despite the high prevalence (57%) of shoulder pain (Myklebust, Hasslan, Bahr et al. 2013). Overuse injuries are less common than acute injuries in rugby, though repeated impacts in contact situations during training or match-play may result in shoulder problems (Morgan and Herrington 2014) that need to be captured using an overuse injury questionnaire.

In an attempt to derive greater information regarding overuse injuries, a questionnaire was given to a group of elite Norwegian junior and senior athletes (n=313 in five different sports) at regular intervals during a three month study period to more accurately record injuries that did not fit into a time-loss category when functional or sport performance limitation occurred (Clarsen, Myklebust and Bahr 2013). The questionnaire on overuse injuries was to be administered to the entire team at regular occasions during the study allowing for the degree of overuse symptoms to be individually monitored and for the injury severity to be based on changes to athletic function and sport performance. The findings highlighted the inadequacy of current accepted injury reporting methods to record overuse injuries, with the new method reporting 75%, rather than 11% of athletes affected during the study. This study acknowledged some limitations, namely that it compares results from different data collection methods and two different injury definitions (time-loss compared to all physical complaints), while also being at risk of only reporting subjective information about the injury. A possible weakness of utilising this method in rugby would be that it would not be comparable to existing data that has used the time-loss injury definition. A benefit of this method is the low reliance on personnel to record injuries which would benefit settings like community youth rugby, where this could be delivered using appropriate software. In sport contexts where there is a lack of support for injury surveillance, self-reporting injuries places some responsibility on the rugby player instead to report their injuries and offers community rugby injury researchers a feasible method to capture injuries where limited personnel are available.

The injury surveillance method is crucial to risk management and a necessary step in identifying risk factors and implementing countermeasures to injury. The recommendation from the consensus statement (Fuller, Molloy, Bagate et al. 2007) is to capture exposure to training and matches, and prospective injury reporting should be carried out by a member of the team's medical staff. Many barriers exist to effectively implementing this surveillance method across all levels of sport, mainly due to the lack of resources available at community levels where the majority of sport participation happens. Consequently, other methods of injury reporting need consideration and evaluation to determine a suitable method for understanding the scope of the injury problem in community rugby where greatest participation occurs. In doing this, however, variations in the registration method can account for some inconsistencies in reported injury rates.

Inconsistencies in time-loss calculations have been seen in community soccer players (n=344, aged 12 to 18 years old) when using weekly injury reporting forms, where injury severity was underreported by the team therapist (Emery, Meeuwisse and Hartmann 2005). In contrast, another study reported that athletic trainers in high school sports (n=18 schools) submitted 98% of the exposure reports compared to only 37% submitted by the coaches, and low agreement with injury diagnosis existed between reports submitted by the therapist and coach (Yard, Collins and Comstock 2009). It is not surprising that in a recent editorial defining the research priorities for injury prevention, the 10 year vision for reducing injury and illness in sport proposes advancing injury surveillance from paper-based to digital tools that permit direct data collection from the athlete, using refined and reliable systems to provide real-time injury surveillance data (Finch, Bahr, Drezner et al. 2017). A new method of injury registration involving prospectively text messaging players (n=228) to report injuries was compared with routine medical staff registration (reference group) in elite female football players (Nilstad, Bahr and Andersen 2014). This new method appeared to be feasible and a convenient tool for reporting injuries though 62% time-loss injuries reported by text messaging compared to 10% reported by medical staff, with congruence of 28% by both methods. A similar proportion of overuse injuries were reported with the corresponding numbers, 87% and 35% respectively. Some players may not want to disclose injuries to the medical staff for fear that this might affect their chances of selection for the next match, which is a potential factor in discrepancies between the reporting methods. Also, limited availability of medical staff at all training sessions would limit the opportunity for injuries to be reported. In lower playing levels in rugby, such as in community youth rugby, the resource does not exist to support the allocation of medical staff and is therefore an obstacle to injury surveillance at this level. A major advantage of using SMS for injury registration is the ease of use and the potential to reach a large sample of players, which could reduce the risk of recall bias and offer a feasible option for injury surveillance.

Self-reported sport injury offers an alternate option to recording injury data; however, this needs to happen in real-time for accurate data (Gabbe, Finch, Bennell et al. 2003). The reliance on accurate recollection of events and injuries sustained by the players is one such issue that can be minimised. Specifically, a shorter recall period and using a clear definition of injury can limit recall bias and improve correct recollection of the details of the injury (Ekegren, Gabbe and Finch 2014). Caution is advised, nevertheless, when further detail than ‘injured or not injured’ is required, as retrospective self-reported injuries were shown to be unreliable in a study on Australian football players (n=70 amateur players) evaluating the accuracy of self-reporting over a 12 month injury history recall period (Gabbe, Finch, Bennell et al. 2003). Evidently numerous challenges exist in monitoring injuries in sport and with further development of digital tools such as mobile devices and SMS, real-time self-reported injury registration offers the potential to collect data directly from athletes to form an integral component of risk management in sport.

Establishing the extent of the problem

Participating in a physically intense, full contact sports like rugby union has an understandably high risk of injury when compared with similar playing levels in other team sports (Brooks and Kemp 2008). Evidence suggests that injuries significantly increase with age (n=210) in the youth community under 9 to 12 age group with 11.9 per 1000 hours compared to under 13 to under 17 age groups with 34.2 injuries per 1000 hours reported (Haseler, Carmont and England 2010). This injury trend is further highlighted in English youth school rugby (n=222) and academy (n=250) players (age, 16 to 18 years old) whose overall match injury was 35 per 1000 hours and 47 per 1000 hours respectively (Palmer-Green, Stokes, Fuller et al. 2013). There were even higher overall match injuries recently reported for academy players (n=132, mean age 17.5 years old), with 77 per 1000 hours in a retrospective cohort study while the injury incidence for non-academy players was almost half (34 per 1000 hours) (Barden and Stokes 2018). In the largest prospective cohort study of injuries in community level rugby union (189 clubs) the overall match injury incidence was lower than some junior playing levels and the elite level, with 16.9 injuries per 1000 hours (Roberts, Trewartha, England et al. 2013). Reported injury rates are highest for male professional players when calculated as overall time-loss match injuries, 81 per 1000 player hours (Williams, Trewartha, Kemp et al. 2013). The injury rates for elite schoolboy rugby players are higher than adult community players and, in some case, comparable to elite professionals which raises concerns about the risk of injury for this playing level. The smaller sample of players in the youth injury data compared to the adult community and elite level players raises the question if the youth data underestimates the scale of injuries at this playing level.

Identifying specific injury locations for these playing levels would be useful to determine injury trends between the playing levels and to inform injury prevention priorities. Head injuries, particularly concussion, were the most common (24%) in the 2015 Rugby World Cup (n=639), followed by knee and hamstring injuries at 17% and 16%, respectively (Fuller, Taylor, Kemp et al. 2017). Knee ligament injuries caused the most days' absence (1507 days) which was followed by hamstring strain and shoulder dislocation accounting for 669 and 321 days, respectively. In the professional men's Super Rugby tournament (n=482) over a five year period, lower limb injuries were most common (50%), followed by 24% upper limb injuries (Schwellnus, Jordaan, Janse van Rensburg et al. 2019). A meta-analysis in senior amateur male rugby players found the knee to be the most commonly injured joint (pooled incidence 3.8 per 1000 hours) followed by the shoulder and thigh, both with injury rates of 3.1 per 1000 hours (Yeomans, Kenny, Cahalan et al. 2018). When we look specifically at this data for junior players, the shoulder was the most common injury location in the U20 Rugby

World Cup (n=3922) (Fuller, Taylor and Raftery 2018) with 18.3 injuries per 1000 hours reported over eight seasons. In elite U17 schoolboys' (n=132) shoulder injuries were found to be the second highest injury location and had the greatest injury burden (553 days) for any specific body location over three seasons (Barden and Stokes 2018). Previously, other researchers have shown that shoulder and knee injuries were the highest reported (both were 4.9 injuries per 1000 hours) in community youth rugby (n=210) (Haseler, Carmont and England 2010). Even when reporting medical-attendance injuries, there were more shoulder injuries (4.4 per 1000 hours; 95% CI:2.3 to 7.6) than knee injuries (3.6 per 1000 hours; 95% CI:1.7 to 6.6) in Australian school level rugby players (n=3585) (Leung, Franettovich Smith and Hides 2017). It is evident that shoulder injuries are a problem in the junior playing age groups and until now, has not been given the focus of preventative efforts to reduce the associated risk of injury.

Short term consequences

The mean number of days lost due to shoulder injuries in professional rugby union players in New Zealand was 37 (n=7920, 95% CI: 25 to 54) (Usman, McIntosh, Quarrie et al. 2015) and, on average, a total of 241 days of training and match play was lost due to shoulder injuries per club per season in professional rugby in England during the 2002-2003 and 2003-2004 season (n=546, 2.86 per 1000 hours) (Headey, Brooks and Kemp 2007). In a cross-section of competition playing levels (n=1475, elite professional, professional club level and under 20 elite players) in Australian rugby teams an average of 25 days were lost due to shoulder injuries (Usman and McIntosh 2013). Shoulder injuries account for a considerable number of days lost and these findings provide impetus for action, from those responsible for the musculoskeletal health of rugby players.

Literature review of the epidemiology of shoulder injuries in rugby

Reviewing the current evidence on shoulder injury epidemiology across all playing levels of rugby union is crucial to grasp the magnitude of the problem posed by these injuries. Evaluating and synthesising the reported injury data for each playing level will permit us to determine the level of risk for players and where our future preventative efforts should be focused. Sixteen studies in adult players (*Table 2*) and eight studies in youth or adolescent players have reported on shoulder injury incidence as injuries per 1000 hours or provided data to allow the incidence to be calculated (Table 3).

Author	Study	Population	Injury definition	Match injury incidence (per 1000 player hours) (range)	Match injury severity (mean days, 95% CI)	Match injury burden[1] (mean days, 95% CI)
(Headey, Brooks and Kemp 2007)	Prospective Cohort (2002-2003, 2003-2004)	Elite male, English premiership (n=546)	Time-loss[2]	8.9 (7.5-10.3)	27 (23-32)	241
(Fuller, Laborde, Leather et al. 2008)	Prospective 2007 RWC	International men (n=626)	Time-loss[2]	9.4 (5.9 to 14.9)	*19.3 (4.4 to 34.3)*	*181.42*
(Fuller, Raftery, Readhead et al. 2009)	Prospective cohort 2008 Super 14 and Vodacom Cup	Professional male (n=813)	Time-loss[2]	Upper limb 20.6% (16.3 to 24.8) Super 14 24.3 (14.5 to 34.1) Vodacom Cup	Not provided	Not provided
(Schneiders, Takemura and Wassinger 2009)	Prospective cohort 2002	Professional male (n=106)	Time-loss and medical attention	13.9% (out of 164) exposure 3140h. 7.26/1000h	Not provided	Not provided
(Usman and McIntosh 2013)	Prospective cohort (2004-2008)	Adult male in colts, grade and elite (n=1475)	Time-loss[2]	8.61	3.4 weeks (25 days)	215.25
(Williams, Trewartha, Kemp et al. 2013)	Meta-analysis (1995-2012)	Senior men's professional	Time-loss[2]	14 (8-25) Upper limb	Not provided	Not provided
(Roberts, Trewartha, England et al. 2013)	Prospective cohort (2009-2012)	English community men's rugby (n=189 clubs)	Time-loss[2]	2.3 (2.0-2.7)	*9.3 weeks (8.1-10.5)*	151.8
(Schwellnus, Thomson, Derman et al. 2014)	Prospective cohort 2012	Professional male (n=152)	Time-loss[2]	16.5 (10.7 to 24.4)	Not provided	Not provided
(Roberts, Trewartha, England et al. 2014)	Prospective cohort 2009 - 2012	Adult community	Medical attendance	23 (22 to 24)	Not provided	Not provided
(Usman, McIntosh, Quarrie et al. 2015)	Prospective cohort (2005-2010)	Elite adult professional men (n=306)	Medical injury incurred medical cost, not all time-loss	12.7 (10.1-15.9)	37 (25-54)	470 (308-717)
(Moore, Ranson and Mathema 2015)	Prospective cohort (2011 – 2014)	International male (n=78)	Time-loss[2]	33.8 (23.1 to 49.2)	111	3751
(Whitehouse, Orr, Fitzgerald et al. 2016)	Prospective cohort 2014	Professional male (n=180)	Time-loss[2]	8.9 (4.41 to 13.45)	59.73 (48.82 to 70.65)	472
(Swain, Lystad, Henschke et al. 2016)	Prospective cohort 2012	Men's amateur (n=125)	Time-loss or medical attention	7.3 (4.3 to 11.5)	Not provided	Not provided
(Fuller, Taylor, Kemp et al. 2017)	Prospective cohort 2015 RWC	Professional male (n=639)	Time-loss[2]	5.8 (2.3 to 9.3)	Not provided	Not provided
(Yeomans, Kenny, Cahalan et al. 2018)	SLR and meta-analysis (1995 to 2016)	Senior amateur male	Time-loss[2]	3.1 (2.4 to 3.7)	Not provided	Not provided
(Schwellnus, Jordaan, Janse van Rensburg et al. 2019)	Prospective cohort (2012 to 2016)	Professional male (n=482)	Time-loss[2]	12.9 (10.6 to 15.7)	Not provided	Not provided

Table 2: Study summary of shoulder incidence, severity and burden in adult male rugby players

[1] Incidence multiplied by severity
[2] any shoulder injury that prevented the player from taking a full parting all training and match play for more than 24 hours from the day of injury

Author	Study	Population	Injury Definition	Match injury incidence (per 1000 player hours) (range)	Match injury severity (mean days, 95% CI)	Match injury burden (days)
(Kerr, Curtis et al. 2008)	Prospective cohort 2005 to 2006	US collegiate (n=66 teams), 17 to 21 year olds	Time-loss	2.16	Not provided	Not provided
(Haseler, Carmont et al. 2010)	Prospective cohort 2008 to 2009	Community youth (n=210), U/9 to U/17	Time-loss	4.9	Not provided	Not provided
(Nicol, Pollock et al. 2011)	Prospective cohort 2008 to 2009	6 Scottish schools (n=470) aged 11 to 17 years	Time-loss	3.32	Not provided	Not provided
(Kawasaki, Ota, Urayama et al. 2014)	Prospective cohort 2012	Male high school (n-378), age 15 to 18 years	Self-reported questionnaire, time-loss (>24 hours)	Dislocation 3.2, all shoulder 8.5 (5.8 to 11.2)	Not provided	Not provided
(Leung, Franettovich Smith et al. 2017)	Prospective cohort 2016	Australian schools (n=3585 players) 9 to 10 years to 17 and 18 years old	Medical attendance	Upper limb 6.3 (26.8%) Shoulder 3.5	Not provided	Not provided
(Fuller, Taylor et al. 2018)	Prospective cohort 2008 to 2016	World Rugby U20	Time-loss	9.09 (18.3%)	Not provided	Not provided
(Barden and Stokes 2018)	Retrospective cohort 2012 to 2015	Academy U16 to U19 (n=132)	Time-loss	Upper limb: AASE 25 (13 to 38), Shoulder: 19 Non-ASSE 9 (5 to 13), Shoulder: 5	Upper limb: AASE 24d (12 to 37) Non-ASSE 24 (12 to 36)	Upper limb: AASE 600 days, Non-ASSE 216 days
(Sewry, Verhagen et al. 2019)	Prospective cohort 2017	SA school (U16)	Time-loss	Upper limb: 7.8 (2.7 to 13)	Not provided	

Table 3: Study summary of shoulder incidence, severity and burden in youth and adolescent male rugby players

The incidence of time-loss shoulder injuries reported at the highest playing level (international cohort) ranged from 5.8 per 1000 hours in the Rugby World Cup in 2015 (Fuller, Taylor, Kemp et al. 2017) to 33.8 per 1000 hours sustained by Welsh international players across a three-year period (2011 to 2014) (Moore, Ranson and Mathema 2015).The findings in the latter study is unprecedently high in relation to all other shoulder injury data for adult rugby players and is also higher than the incidence reported over eight seasons at the highest playing level for the junior players (9.09 per 1000 hours) at the U-20 Rugby World Cup (Fuller, Taylor and Raftery 2018). The study on the Welsh international players applied a rigorous data collection process and highlights that other methodological issues such as the level of the medical staff training, injury surveillance methods, player monitoring may affect reported injury rates. In other studies where collated results from multiple teams at a competition may actually underestimate the risk of injury and be a contributor to lower injury rates reported. Shoulder dislocations accounted for the highest injury burden for English professional players (1703 days absence) (Headey, Brooks and Kemp 2007) and was the second highest injury burden for the U-20 Rugby World Cup players though it accounted for more days absence (2865 days) (Fuller, Taylor and Raftery 2018).

The incidence of shoulder injuries amongst English academy youth players (n=132) reported in a recent retrospective study conducted over three seasons (2012 to 2015) was concerningly high (19 per 1000 hours) (Barden and Stokes 2018). This injury rate is contrary to the trend of overall injuries increasing with age as a lower incidence of shoulder injuries is seen in professional level South African Super Rugby teams (16.5 per 1000 hours) (Schwellnus, Thomson, Derman et al. 2014). At the lower youth playing level (under 15 to 18 age group) the shoulder incidence (8.5 per 1000 hours) is almost half that of the injury rate for academy players as seen in a prospective cohort study using a self-administered injury questionnaire (Kawasaki, Ota, Urayama et al. 2014). The injury data was collected from a self-administered questionnaire which is a different injury surveillance method to other studies and is an acknowledged study limitation as it may lead to under-estimation of injuries due to recall bias. This injury rate was then followed by premier club players in New Zealand (mean age 21.8±2.8 years) with 7.26 per 1000 hours reported (Schneiders, Takemura and Wassinger 2009). A considerably lower incidence (2.3 per 1000 hours) of time-loss injuries than other player levels was reported for adults (semi-professional, amateur and recreational) in a prospective cohort study (Roberts, Trewartha, England et al. 2013). This data reveals a higher incidence of shoulder injuries is seen in the academy youth playing level when using the same injury definition.

Methodological design

There are a number of variations in research design and methods of analysis that should be considered when reviewing the conclusions reached in epidemiological research. The influence of the following methodological issues is proposed to be important in sport epidemiology (Brooks and Fuller 2006).

- Method of reporting injuries (number, proportion and incidence)
- Method of injury data collection (medical reported, self-reported and coach reported)
- Injury definition (time-loss, missed match, diagnostic assessment and surgery)
- Training and match injuries combined

Studies that did not report upper limb or shoulder injury data as injury incidence per 1000 player hours or did not provide the data for this to be calculated are discussed in terms of their methodological design. Data collection for prospective cohort studies were carried out by suitably qualified injury management personnel in most of the reviewed studies, with two studies utilising trained injury surveillance coders to record injuries (Sabesan, Steffes, Lombardo et al. 2016, Swain, Lystad, Henschke et al. 2016) and one study opting to use a self-reporting injury questionnaire in high school players (Kawasaki, Ota, Urayama et al. 2014). Sabesan et al. (2016) analysed data on rugby injuries that reported to the emergency department in the United States from the National Electronic Injury Surveillance System. In the United Kingdom, such a database does not exist in emergency departments and not all injuries are referred to the emergency department, which suggests that injury data based on emergency department records may under-estimate the actual extent of injuries. In addition to injuries resulting from playing rugby, Sabesan et al. (2016) also included injuries involving rugby equipment and spectators at rugby events. Distinguishing from these causes of injury is not possible as the mechanism of injury involved was not presented. A meta-analysis of injuries in youth rugby players encountered great variability in data collection procedures with only eight out of thirty-five studies adhering to the consensus statement for data collection procedures in rugby research (Freitag, Kirkwood, Scharer et al. 2015). The probability of a player being injured over a season had a wide range from 6% to 90% which calls for a radical improvement to the sport injury surveillance in hospitals and schools in the UK.

The majority of studies have reported specifically on shoulder injuries as a sub-location for adults with two studies reporting more broadly on adult upper limb injuries. Furthermore, the injury data is reported differently with the incidence of upper limb injuries reported in a meta-analysis as 14 per 1000 hours (Williams, Trewartha, Kemp et al. 2013) while Fuller et al. (2009) reported upper limb injuries as a proportion of injury location (20.6%). It is acknowledged that the results presented as proportions of injuries do not account for different levels of exposure to risk of injury and are of limited value (Brooks and Fuller 2006). Most studies reported on the injury incidence per 1000 player hours with three studies reporting injuries as a proportion in percentage figures, where one study provided the data allowing the incidence per 1000 hours to be calculated.

Three youth/ adolescent studies (Palmer-Green, Stokes, Fuller et al. 2013, Freitag, Kirkwood, Scharer et al. 2015, Palmer-Green, Stokes, Fuller et al. 2015) and two studies in the adult playing level (Fuller, Raftery, Readhead et al. 2009, Williams, Trewartha, Kemp et al. 2013) only reported upper limb injuries and did not include the incidence for the sub-location for shoulder injury data. There also existed variation amongst this data with injuries being reported as a proportion of injuries or as injuries per 1000 hours. Reviewing studies that adhered to the 'Consensus statement on Injury Definitions and Data Collection Procedures for Studies of Injuries in Rugby Union' (Fuller, Molloy, Bagate et al. 2007) permits comparability of their findings however the injury definition was unclear in four studies (Schneiders, Takemura and Wassinger 2009, Usman, McIntosh, Quarrie et al. 2015, Swain, Lystad, Henschke et al. 2016, Yeomans, Kenny, Cahalan et al. 2018).

Since much variation exists in the study design employed across the literature on upper limb/shoulder injuries (prospective and retrospective cohort studies), injury data collection methods (medical personnel, injury data coders and self-reported questionnaires), injury definition and injury reporting (per 1000 hours and proportion of injury) and the level to which injury sub-locations have been reported (upper limb and shoulder injuries), the literature is not directly comparable. Clearly it is paramount for studies to follow the same injury surveillance procedures in order to allow the magnitude of shoulder injuries across all playing levels in rugby to be determined.

Glenohumeral instability events are high in elite and contact sport when compared to other collegiate sports and are evenly split between new (53%) and recurrent (47%) cases for this type of injury (Owens, Agel, Mountcastle et al. 2009); though, identifying the type of treatment rendered for these athletes was not available through the database used. In another group of players (n=34, age range 17 to 33 years old) who had their shoulder injuries surgical stabilised, 65% returned to playing rugby (14 played at professional playing level and 30 non-professional) (Neyton, Young, Dawidziak et al. 2012). In a retrospective case controlled study over seven years, a lower rate of recurrence (21%) was seen amongst younger rugby players (n=169, aged 12 to 18 years; playing at school, amateur club, academy or professional level) at a minimum of two year post-surgery (87% managed surgically), with academy players having the highest recurrence of 11% (Hodhody, Mackenzie and Funk 2016). It was noted that comparison with other studies was not possible as it was not clear if pre-management or post-management of injury was considered (Hodhody, Mackenzie and Funk 2016). Commitment to rehabilitation, availability and resources was deemed to be better at higher playing levels as accounted for by Hodhody et al. (2016) with lower levels of recurrence amongst professional players. The latter study stated that where there is a risk of injury like shoulder dislocation, there needs to be better parity in the injury management and pertaining education available to all playing levels to reduce the risk of recurrence. The significant implications of shoulder injuries are also evident amongst English professional rugby union players, where it is reported to be the most common reason for retirement in the 10 year period prior to 2005 (Brooks, Fuller, Kemp et al. 2005). Exposing the significant consequences of shoulder, specifically at a young age, implores more focused efforts to reduce this associated risk.

Mechanism of injury

A limitation of previous studies reporting injury incidence and severity has been the lack of detail about injury mechanisms. The tackle has been reported as the most common inciting event for all injuries across all playing levels (Quarrie and Hopkins 2008, Fuller, Ashton, Brooks et al. 2010, Burger, Lambert, Viljoen et al. 2014). Specifically, previous research has shown the tackle to be a significant risk factor for acute shoulder injuries (Fuller, Brooks, Cancea et al. 2007, Fuller, Ashton, Brooks et al. 2010). There was almost an even split with being tackled (n=7 studies) (Fuller, Laborde et al. 2008, Fuller, Raftery et al. 2009, Williams, Trewartha et al. 2013, Roberts, Trewartha et al. 2013, Moore et al. 2015, Whitehouse, Orr et al. 2016, Fuller, Taylor et al. 2017) or tackling (n=8 studies) (Headey, Brooks et al. 2007, Schneiders, Takemura et al. 2009, Usman and McIntosh 2013, Schwellnus, Thomson et al. 2014, Usman, McIntosh et al. 2015, Swain, Lystad et al. 2016, Yeomans, Kenny et al. 2018, Schwellnus, Jordaan et al. 2018) as the injury event for all injuries amongst adult players with Roberts et al. (2014) not recording the injury mechanism (*Table 2*). In adult players, one study reported that tackling resulted in more glenohumeral joint injuries while the ball carrier sustained more acromioclavicular and sternoclavicular injuries across all playing levels (Usman and McIntosh 2013).Tackling (Kerr, Curtis et al. 2008, Leung, Franettovich Smith et al. 2017, Barden and Stokes 2018) or being tackled (Nicol, Pollock et al. 2011, Fuller, Taylor et al. 2018, Sewry, Verhagen et al. 2019) was equally reported in three studies each as the most common inciting event for all injuries in youth players. Somewhat contrary results were reported in an analysis examining shoulder dislocations and subluxations caused by the tackle across all playing levels in France (n=1.4 million) which concluded that there were more tackled (74.7%) than tackling (25.3%) injuries, except for professional players where they were all tackling injuries (Bohu, Klouche, Lefevre et al. 2015). In two studies reporting specifically on shoulder match and training injuries in youth players, tackling was the most common inciting event (Palmer-Green, Stokes, Fuller et al. 2013, Palmer-Green, Stokes, Fuller et al. 2015). These studies confirm that the tackle accounts for the most common phase of play to result in injury across all playing levels. Determining the mechanism of injury and understanding the potential injuries that may occur is an important step to developing preventive strategies for shoulder injuries in rugby.

Multiple factors play a role in the resultant injuries caused by the tackle, of which, tackle technique is one associated factor (Burger, Lambert, Viljoen et al. 2017). Some examples of research methodologies and designs that can be used to analyse injury mechanisms include case-control studies, cohort studies and statistical modelling. Numerous methodological approaches exist to describe the inciting event which include; interviews with the athlete, video analysis, clinical studies using diagnostic imaging, in vivo studies, cadaveric studies, mathematical modelling and simulation of injuries (Verhagen and van Mechelen 2010). Video analysis of the tackle is a method used to describe the contributing mechanisms and characteristics of shoulder injuries. The video image quality, viewing angles, uncalibrated video sequences, uncertainty in determining segment attitudes and estimating joint angles are considered a limitation of analysis for estimating kinematics, although model-based image matching techniques have been described to account for this source of error (Krosshaug et al. 2005). Video analysis of 11 tackles on 11 elite rugby players that led to dislocation were categorised into hand, arm or shoulder tackles to show the relevance of the mechanism of injury (Maki, Kawasaki, Mochizuki et al. 2017). The injury mechanisms they describe revealed that an inappropriate posture of the tackler due to the ball carriers' sudden changes in direction imperils the tacklers shoulder into increasingly vulnerable ranges of motion, such as >90º glenohumeral abduction, horizontal abduction and in some cases external rotation at the point of impact with the ball carrier. These findings are in agreement with other studies identifying that arm position levered forcibly backward resulted in shoulder dislocation during the tackle (Longo, Huijsmans, Maffulli et al. 2011, Crichton, Jones and Funk 2012, Usman, McIntosh, Quarrie et al. 2015). These studies indicate the similarities in the mechanism of injury and potential injuries that may result in the tackle. Introducing interventions that may contribute to the optimal functioning of the shoulder in the tackle would be advantageous in reducing the risk of injury.

Other common mechanisms and associated shoulder injuries have been reported in studies using video analysis (Crichton, Jones and Funk 2012, Usman, McIntosh, Quarrie et al. 2014). Video footage of 24 elite rugby players with 24 injury events was analysed and identified three mechanisms of injury. The following common injury mechanisms based on the 24 injury events were associated with structural shoulder injuries. Try scorer injury occurs when diving and reaching the ball carrying hand forward to score a try the shoulder may subluxate or dislocate, resulting in a Bankart lesion, superior labrum anterior-posterior lesion (SLAP) or rotator cuff lesion. When tackling an opponent, anterior dislocation is most common with the risk of a Bankart lesion, SLAP or humeral avulsion of glenohumeral ligament (HAGL). Direct impact to the shoulder with the ground or another player includes a combination of bony glenoid lesions, complex labral tears or a rotator cuff lesion. A posterior driven force from falling onto a flexed elbow can result in posterior labral tears and reverse HAGL. It is acknowledged that these injuries are based on a small number of cases and the generalizability of the results are limited.

The findings from these studies help to identify a number of common mechanisms that may contribute to acute shoulder injuries in rugby. Understanding the mechanisms of injuries can guide rehabilitation and prevention options in sports where high collision forces are common.

It seems that players should be taught to avoid vulnerable arm positions when tackling and when coming into contact with the ground to minimise the risk of injury. In addition, other researchers have proposed that a well-conditioned player may better withstand the impact of the tackle, thereby minimising their injury risk (Gianotti, Quarrie and Hume 2009, Horsley and Herrington 2014).

A complex interaction between intrinsic and extrinsic risk factors exist that renders the athlete susceptible to injury during the inciting event. Following an injury there are various mechanisms that contribute to the increased risk of developing long-term musculoskeletal conditions such as osteoarthritis. Bennell et al. (2012), outlines a cascade of events, such as progressive tissue damage, inflammation and matrix degeneration that follows joint injury. Subsequently, injury can alter biomechanics and impair neuromuscular function leading to improper load-bearing to areas that are not able to withstand the load. The schematic in figure 3 below, outlines the proposed relationship between sport and the development of osteoarthritis and highlights areas for intervention to reduce the burden of disease.

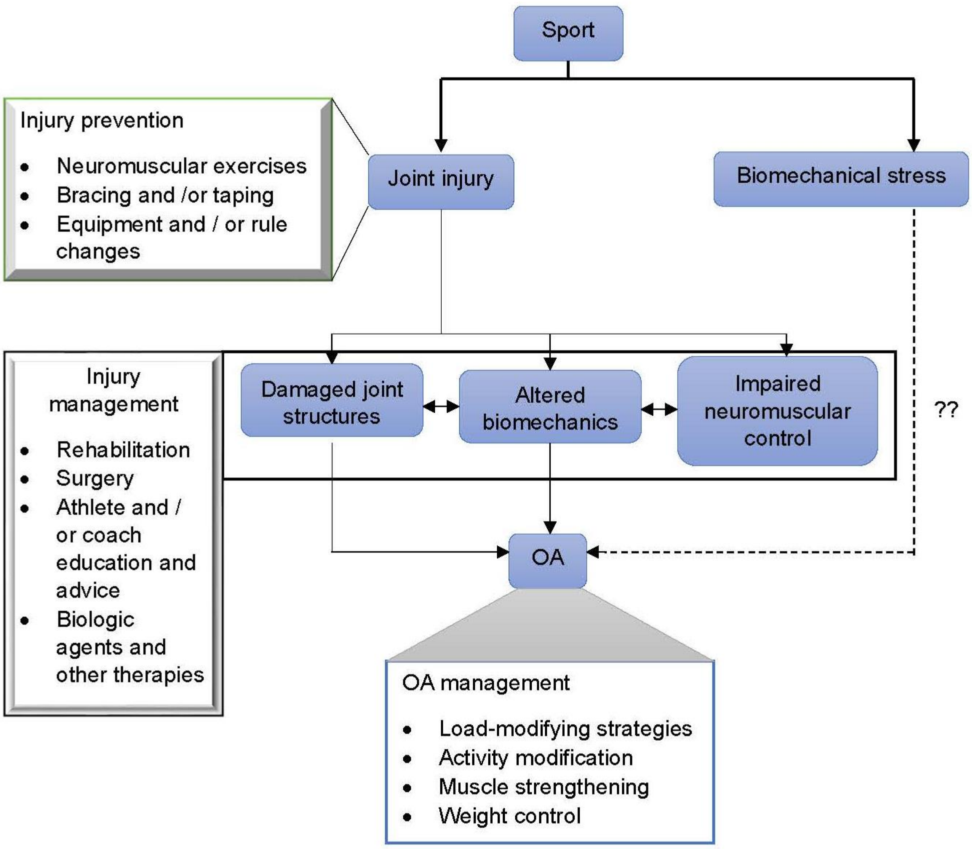

Figure 3. Relationship between sport and osteoarthritis. (Bennell et al. 2012)

Long term consequences

Added to the significant acute effects of shoulder injuries is the risk of early onset of degenerative joint changes. These changes have been documented in longitudinal studies showing shoulder arthropathy in sports people following shoulder dislocation. Radiographic follow-up 25 years after shoulder dislocation was evaluated in a multi-centre study (n=255, aged 12 to 40 years old) (Hovelius and Saeboe 2009) using the Samilson-Prieto classification for glenohumeral osteoarthritis to grade the degree of arthropathy on radiographs and the Disability of Arm, Shoulder and Hand (DASH) outcome questionnaire to rate the subjective assessment of shoulder function. The group that sustained a traumatic shoulder dislocation whilst playing sport had the highest percentage of moderate/ severe arthropathy (37%), and when mild arthropathy was included the figure rose to 56%. These findings led the researchers to affirm that the trauma of dislocation has long-term biological effects on joint physiology, though they were cautious to point out that the clinical impact of radiographic arthropathy may be debated. A higher percentage of patients (69%) were seen to have radiographic signs of osteoarthritis (stage 1 - 4) in a long-term study (mean follow up time was 28 years) evaluating the outcome of patients who underwent shoulder surgery (n=49) (Bankart procedure) for recurrent anterior shoulder instability (Fabre, Abi-Chahla, Billaud et al. 2010). This was a retrospective study that used a shoulder stability score and the development of glenohumeral osteoarthritis as outcome measures. Though there was a high level of radiographic changes seen, forty patients (82%) returned to their previous level of sport, including 31 rugby players. These comparable long-term follow up rates would suggest the emergence of glenohumeral osteoarthritis is part of the natural process for unstable shoulders. Reducing the risk of shoulder dislocation and instability in rugby would therefore be advantageous to prevent the development of long-term shoulder conditions for younger players.

Other forms of imaging such as computer tomography (CT) osteoabsorptiometry, has been used to determine the pattern and changes of bone mineralisation which represents the long-term distribution of mechanical loading in the relevant joint. A group of men with traumatic anterior unilateral shoulder instability (n=25 rugby players and n=17 non-athletes) were prospectively investigated using CT imaging to address the long-term stress distribution in the shoulder joint due to rugby (Kawasaki, Sashi, Moriya et al. 2013). The mean time elapsed from the first injury was 3.3 years in both groups. The study demonstrated a significantly higher overall mineralisation in the shoulders of the rugby players compared to the controls ($p<0.01$), representing the mechanical changes in the shoulder regardless of history of instability. These degenerative changes in the rugby shoulder are suggested to be followed by osteoarthritis more frequently than in the general population (Kawasaki, Sashi, Moriya et al. 2013).

Financial costs

The consequences of a sport injury may have a direct physical and psychological health cost to the injured player, who may also incur healthcare costs and other indirect expenses (Cumps, Verhagen, Annemans et al. 2008). Financial costs may be grouped into direct costs which include those related to treatment and rehabilitation, whereas time away from work / education and childcare are considered indirect costs (Collard, Verhagen, van Mechelen et al. 2011). In a study looking at the economic burden of youth rugby injuries (n=190), Brown et al., (2014) found the cost of medical follow up treatment to be $731 USD per injury. Upper extremity injuries and fractures resulted in the highest costs (based on a time-loss definition) for players who had medical insurance compared to those that did not ($1242 USD; 95% CI, $445 to $2269 USD). Furthermore, severe injuries may also result in an extended course of rehabilitation which could influence time away from work / education. The extent of injuries is therefore far reaching, extending beyond the monetary cost.

In a similar collision sport, King et al. (2011) found that, according to Accident Compensation Corporation data, the shoulder was the second most frequent and third most costly injury in rugby league in New Zealand between 1999 and 2007 (King, Hume, Gianotti et al. 2011). The researchers raised concerns that these costs nearly quadrupled whereas the yearly number of claims for shoulder injuries tripled in the same period. It was thought that this increase in cost may reflect the change in severity of shoulder injuries and tackle styles employed. Though these studies were conducted in countries that use a different healthcare system to the United Kingdom, in the absence of data from the National Health Service, it is prudent to acknowledge the healthcare cost implications for the management of sport injuries. Socioeconomic evaluation of sport injury aids policy makers in deciding whether or not to implement or fund new interventions to address the direct and indirect effects of sports injury. In this context, the literature on the monetary cost of shoulder injuries supports the need for preventative efforts to be implemented.

Public profile

The publicity received from rugby's inclusion in the 2016 Olympics required World Rugby to demonstrate a significant level of responsibility for player welfare, and in doing so the governing body put into effect playing laws which were enforced by match officials (referees, touch judges and television match officials). Increased media coverage and public concerns about the high incidence of injuries such as concussion in rugby, likely has been a catalyst to changes in playing laws about dangerous play. The resources required for this level of match officiating is not available to community youth teams and while rugby laws may still be imposed from the governing body, there is a need for other preventative measures like neuromuscular training programmes to be considered at this playing level. These factors are important to recognise as they may influence the public perceptions about the risk of injury in rugby which may be beneficial or prove a hindrance when considering the acceptance of preventative measures in rugby.

The impact that collision sport has on shoulder health, continued sport participation, and associated socioeconomic costs provides a valid argument for why injury surveillance and prevention research should be a priority across collision sport. The focus on the shoulder addresses an area that has previously been neglected in the literature though clearly needs further research investment. The consequences of shoulder injury have been reported to contribute to the most days absent and are a common reason for surgical intervention in collision sport. In addition, shoulder injury is associated with adverse biological changes and direct and indirect financial costs. Therefore, the next step to trying to minimise the risk of shoulder injuries in rugby involves investigating the modifiable risk factors to inform evidence-based preventive approaches.

Risk Factors

Stage two of the sport injury prevention frameworks aim to understand why injuries occur, which helps to clarify what factors injury prevention programmes need to target which may be developed and analysed in case studies, biomechanical and biomedical engineering research (van Mechelen, Hlobil and Kemper 1992, Finch 2006). Risk factors for sport injuries can be divided into two main categories consisting of internal personal factors (‘intrinsic’) and external environmental factors (‘extrinsic’) (Bahr and Holme 2003). Intrinsic risk factors in sports include age, gender, anthropometric characteristics, fitness, psychological characteristics, health status and injury history. The nature of the sport, environmental conditions and equipment are regarded as extrinsic risk factors. To illustrate, beginning a playing season with an injury emerged as a predictor of injury incidence and of missed play in cohort of 258 rugby players (Quarrie, Alsop, Waller et al. 2001).

Playing position

The influence of playing position on shoulder injuries was investigated in a number of studies with some contradictory findings. A greater incidence of shoulder injuries was reported amongst back five (12.2 per 1000 hours) and halves (13 per 1000 hours) compared to other positions (3 to 3.7 per 1000 hours) in elite male rugby players (Best, McIntosh and Savage 2005), with other authors reporting that elite French forwards sustained more shoulder injuries than backs (Nove-Josserand, Hager and Zilber 2007). Back row forwards and the fullback position were also found to have an increased risk of shoulder injuries leading to anterior reconstruction for shoulder instability (Sundaram, Bokor and Davidson 2011). Understanding the types of injuries sustained by specific playing positions would allow for position specific conditioning and preventative efforts to be developed in order to minimise the risk of injury. The influence of playing position on shoulder injuries is currently unknown at lower playing levels and is recognised as a gap in the literature for future work to address.

Shoulder laxity and instability

Knowledge about normal and abnormal functional anatomy of the shoulder is necessary when considering the intrinsic risk factors and potential mechanisms that contribute to injury (Meeuwisse, Tyreman, Hagel et al. 2007). The shallow articular design of the glenoid fossa permits a large range of movement which detrimentally compromises shoulder joint stability. Shoulder stability is attributed to static and dynamic stabilisers such as the capsuloligamentous components and the rotator cuff muscles (Lephart and Jari 2002). The integrity of the capsuloligamentous structures and neuromuscular receptors constitutes the highly integrated passive and active control systems that together, with the central nervous system, are involved in the neurosensory control of glenohumeral stability. Mechanical deformation of the joint capsule stimulates these receptors and provides greater position sense acuity. Trauma or surgery to these highly specialised neural control systems can decrease proprioception due to the loss of afferent neural input and jeopardise mechanical stability of the shoulder joint (Vangsness, Ennis, Taylor et al. 1995). Proprioception is described as the combination of joint position sense (being able to position the limb in space) and kinaesthesia (ability to perceive active and passive motion) which is necessary for normal muscle coordination and timing. Describing the anatomical design of the shoulder helps to emphasise why the most mobile joint in the body is so vulnerable to injury.

Shoulder joint laxity can predispose an athlete to shoulder instability (Borsa, Laudner and Sauers 2008). Glenohumeral laxity is the physiological range that the humeral head can passively translate on the glenoid fossa that is asymptomatic, whereas shoulder instability is a clinical condition in which unwanted translation of the humeral head on the glenoid results in symptoms such as pain, apprehension, subluxation and dislocation (Lewis, Kitamura and Bayley 2004, Morita and Tasaki 2018). Laxity is associated with instability, and patients with shoulder instability exhibit several abnormal physical characteristics that may be caused by a combination of structural and neurological factors such as shoulder joint articular lesions and abnormal muscle patterning, respectively (Jaggi and Lambert 2010).

Researchers have investigated the effects that repeated shoulder impacts have on the sensorimotor system and muscle patterning. Studies examining shoulder instability and joint position sense have been conducted to evaluate the static system while electromyographic studies have provided insight into the role of the dynamic system (Herrington and Horsley 2009, Morgan and Herrington 2014). Irrespective of how the shoulder joint's passive restraints are evaluated (e.g., using sonography, hypermobility rating scales or orthopaedic tests), rugby players with loose or hypermobile shoulders have been shown to be at a greater risk of shoulder injuries (Stewart and Burden 2004, Cheng, Sivardeen, Wallace et al. 2012, Ogaki, Takemura, Iwai et al. 2014, Owens, Campbell and Cameron 2014). It has also been shown that repeated impacts from tackling jeopardises the shoulder's proprioception and kinaesthetic feedback system, which may compromise the shoulder enough to sustain an injury (Herrington, Horsley, Whitaker et al. 2008, Morgan and Herrington 2014). Indeed, these alterations may affect the muscular system's ability to dynamically control the shoulder and consequently result in injury (Herrington and Horsley 2009).

Repeated tackle collisions have the potential to alter the dynamic control of the shoulder, which could reduce the ability of the shoulder girdle to resist high deceleration forces at the point of impact and result in injury (Herrington, Horsley, Whitaker et al. 2008, Morgan and Herrington 2014, Faria, Campos and Jorge 2017). These studies were repeated measures tackle simulation tasks that categorised the effects of tackling on shoulder function. The findings from this research highlights sensorimotor deficits and decreases in muscular activity of the shoulder following repeated tackle impacts in the laboratory. As these were controlled simulations in an attempt to reducing other confounding factors, the generalisability of the conclusions may not be representative of match play or training situations where other known injury risk factors such as player behaviour exists. Other studies identified the four common mechanisms of injury in rugby, identified by video analysis (Crichton, Jones and Funk 2012), that lead to shoulder instability showed that damage to the glenoid labrum results in all cases and injury to the rotator cuff results in two of the four described mechanisms (Funk 2016). It is the injury to the capsuloligamentous structures, such as the glenoid labrum, that can result in proprioceptive deficits that compromise the coordinated motor patterns, reflex activity and joint stiffness necessary for shoulder joint stability (Myers and Lephart 2002). Ultimately the damage to the mechanical restrains and sensorimotor contribution to joint stability may contribute to re-injury, which is commonly seen in the shoulder (Jaggi and Alexander 2017) however the temporality of this association remains inconclusive. Important associations between biomechanical and neuromuscular factors can be considered when kinematic changes are evaluated along with neuromuscular changes in the context of how the player prepares for the impact.

The association between shoulder laxity and shoulder dislocation was investigated in a retrospective cohort study involving 169 professional rugby players with stable shoulders and 46 players with shoulder instability (Cheng, Sivardeen, Wallace et al. 2012). Humeral head translation was used to determine shoulder laxity and was measured using real time ultrasonography (RTUS). Shoulder function was evaluated using two questionnaires (Western Ontario Shoulder Instability Index and Oxford Shoulder Instability Score) and an apprehension test. Both shoulders were measured in the healthy players and uninjured shoulders were measured in the injured player group. Healthy players had similar shoulder laxity bilaterally, while the injured players had significantly higher shoulder laxity in their uninjured shoulders than healthy players ($p < 0.05$), implying that a loose shoulder may be vulnerable in collisions (Cheng et al. 2012).

The relationship between ligamentous laxity and injury incidence was also seen in a prospective cohort study of 51 male rugby players using an adapted version of the Beighton-Haron scale to measure general hypermobility (Stewart and Burden 2004). Shoulder injuries were the third most common injury reported and players who were hypermobile had significantly more injuries (116.7 injuries per 1000 match hours) compared to their ‘tight’ shoulder counterparts (43.6 per 1000 hours, $p=0.035$). This finding shows that players with inherent ligament laxity, not caused by trauma, could be disadvantaged by the increased risk of injury in rugby. It would be sensible for these players to consider other sports that do not pose a high risk of ligament injury. In addition, identifying players at risk of injury by the Beighton-Horan assessment seems justifiable given the short duration required to complete the test and the potential to minimise the risk of injury.

Clinically assessed shoulder laxity and instability have been shown to be associated with an increased risk of shoulder injury in rugby players (Ogaki, Takemura, Iwai et al. 2014) and military athletes (Owens, Campbell and Cameron 2014), respectively. The association between shoulder injury risk factors, such as laxity, and subsequent shoulder injury was also evaluated in the aforementioned prospective cohort study by Ogaki et al. (2014) involving 69 elite collegiate rugby players. It was found that players with a positive load and shift test had a higher shoulder injury rate (odds ratio [OR] = 2.55; 95%CI, 0.92 – 7.06, $p=0.07$) than players with a negative load and shift test (Ogaki et al. 2014). It is worth noting that a small sample size (n=69) and a wide confidence interval with a lower limit close to zero warrant caution when drawing conclusions from the findings in this study. However, risk factors for traumatic shoulder instability were also evaluated in a prospective cohort study including 714 military personnel who participated in athletics (Owens et al. 2014). Participants with a positive apprehension sign on physical examination were nearly three times more likely (hazard ratio [HR]) 2.96; 95% CI, 1.48 – 5.90; p=0.002) to experience instability and those with a positive relocation sign were nearly five times more likely (HR, 4.83; 95% CI, 1.75 – 13.33; p=0.002) to experience shoulder instability. It can be concluded from this evidence that increased shoulder laxity is associated with instability, suggesting that identifying rugby players who are lax may allow for countermeasures to be implemented to reduce their risk of sustaining an injury. Currently there are no preventative measures in place to target the sequela that leads to shoulder instability, warranting further investigation.

Assessment of shoulder instability

The Stanmore Triangle is a classification system used to describe the three main sub-groups of shoulder instability and the unique feature of this approach is the recognition that the presentation of shoulder instability can change with time (Lewis, Kitamura and Bayley 2004). The continuum of these polar pathologies is labelled as type I-III (Lewis et al. 2004). Polar type I instability results from trauma to the shoulder and is characterised by structural damage, primarily due to a disruption to the capsulolabral complex. Polar type II and III tend to exhibit poor scapular control, abnormal muscle activation, altered trunk stability and impaired balance. Patients presenting with the type II exhibit positive anterior apprehension (due to excessive anterior capsular laxity, scapular dyskinesis, tight posterior capsule, muscle imbalances and congenital labral pathology), sulcus sign, excessive external rotation (ER) and reduced internal rotation (ER) (glenohumeral internal rotation deficit (GIRD). Polar type III is regarded as a muscle patterning instability and comprises aberrant activation of large muscles and simultaneous suppression of the rotator cuff. Abnormal muscle activation is recognised to contribute to structural causes of both traumatic and atraumatic shoulder instability by leading experts at the Shoulder and Elbow Unit, Royal National Orthopaedic Hospital which is recognised as one of the largest units in the United Kingdom (Jaggi, Noorani, Malone et al. 2012). These shoulder specialists emphasised that unless the muscle patterning imbalance is eliminated, attempts at management of shoulder instability will fail. This instability classification system is useful as it demonstrates the continuum between pathologies over time and can direct clinicians toward beneficial interventions for addressing specific impairments.

Shoulder instability and laxity are routinely assessed with orthopaedic tests in clinical practice, and using instrumented devices or imaging techniques in scientific research studies (Bahk, Keyurapan, Tasaki et al. 2007). In clinical practice, shoulder laxity is diagnosed by a cluster of orthopaedic tests, allowing clinicians to classify the degree of laxity present (Cook 2014). This involves the patient being in a relaxed position and the clinician passively translating the humeral head on the glenoid in the desired direction (anterior, posterior or inferior). Due to the shoulder's wide range of normal laxity values, orthopaedic tests may be difficult for clinicians to interpret. In addition, it is difficult to standardise the amount of force required to translate the humeral head, which may limit the test's reliability (Eshoj, Ingwersen, Larsen et al. 2018). For these reasons, clinical tests used to evaluate laxity in day-to-day clinical practice are not always sensitive enough to detect the subtle increases that may develop from repeated impacts to the shoulder during sport. Clearly then this presents a barrier to understanding the aetiology of shoulder injuries in rugby and hinders the instigation of preventive interventions.

Real time ultrasound (RTUS) to measure the anterior translation of the humeral head offers a more quantifiable objective approach that is a non-invasive, rapid measurement tool in practice; however, there are a number of reported limitations using these methods. With RTUS, the anterior translation of the humeral head distance is measured in relation to the perpendicular distance between the most anterior aspect of the humerus and the scapula neck. There are several challenges to this technique which have been acknowledged in the literature, including difficulty in imaging deep lying anatomical landmarks (Yeap, McGregor, Humphries et al. 2003, Joseph, Hussain, Pirunsan et al. 2014, Rathi, Taylor, Gee et al. 2016), anatomical variations (Alashkham, Alraddadi and Soames 2017) and in some cases bone loss may contribute to parts of the glenoid being absent (Favard, Berhouet, Walch et al. 2017). Other imaging approaches exist, such as magnetic resonance imaging which has been used to demonstrate the risk of shoulder injury in military athletes (Owens, Campbell and Cameron 2014). Yet, in terms of accuracy, cost and safety, RTUS is regarded as the best option (Roy, Braën, Leblond et al. 2015). Due to the apparent issues using the deep lying anatomical landmarks as described by Court-Payen et al. (1995), more superficial lying bony landmarks were suggested by using the acromion-greater tuberosity (AGT) distance, described in measuring glenohumeral subluxation (Park, Kim, Sohn et al. 2007). Incorporating RTUS and these superficial landmarks when assessing shoulder laxity, may offer a more sensitive measurement outcome to detect the effects of an intervention on glenohumeral joint laxity.

The AGT distance measured using RTUS has demonstrated good to excellent inter-rater reliability with novice raters in healthy participants (ICC) 0.61 – 0.87) (Kumar and Attwood

2017), has been used in patients with subacromial impingement syndrome (Cholewinski, Kusz, Cielinski et al. 2008) and in those with glenohumeral subluxation following stroke (Kumar, Cruziah, Bradley et al. 2016). The AGT measurement is appealing as it may be used by novice therapists with little training using the method and has proven to be very reliable when using a portable machine. These bony landmarks (acromion and the greater tuberosity of the humerus) for measuring the AGT distance are appropriate for inferior glenohumeral laxity, while evaluating anterior glenohumeral translation requires imaging different bony landmarks. The superior surface of the coracoid process and the superior aspect of the humeral head were identified as the hyperechoic bony landmarks that define a horizontal plane to be followed during dynamic shoulder examination (Court-Payen, Krarup, Skoldbye et al. 1995, Krarup, Court-Payen, Skjoldbye et al. 1999, Cheng, Sivardeen, Wallace et al. 2012, Henderson, Worst, Decarreau et al. 2016). These landmarks used to evaluate humeral translation have demonstrated good test-retest reliability (ICC 0.828) in professional rugby players (n=10, mean ±SD age 26±2.7 years) (Cheng, Sivardeen, Wallace et al. 2012) and also in healthy college students (n=25, mean age 26 years) (intra-rater reliability 0.78) (Henderson, Worst, Decarreau et al. 2016). These methods address the concern of needing a powerful fixed machine to visualise deeper lying anatomical structures by demonstrating that a portable machine can be used with confidence when measuring the AGT distance. This would be advantageous in field-testing rugby players' shoulders to determine the effect of an intervention to address shoulder laxity.

Numerous methods have been described to translate the humeral head using equipment that is not readily available in practice, which include using an instrumented arthrometer (Borsa, Sauers and Herling 1999, Krarup, Court-Payen, Skjoldbye et al. 1999), a spring-loaded rod (Krarup, Court-Payen, Skjoldbye et al. 1999) and a custom made chair and weighted pulley system (Cheng, Sivardeen, Wallace et al. 2012). Other methods describe applying a set force to the humeral head using a pull – push handheld dynamometer which is more readily available in practice (Joseph, Hussain, Pirunsan et al. 2014, Henderson, Worst, Decarreau et al. 2016). However, the ability to apply pressure using a handheld dynamometer to passively translate the humeral head can also be variable, as the force applied accumulates from the moment it is applied to the soft tissue structures and before it has been applied to the joint. In muscular athletes, the designated force (90 Newtons) is often reached before enough force has been applied to effect translation of the joint (Joseph, Hussain, Pirunsan et al. 2014, Rathi, Taylor, Gee et al. 2016). The application of these methods is also questionable in a rugby playing population as the exact impact vector is so variable to the posterior shoulder during a shoulder injury (Funk 2016). In contrast, by examining the findings from biomechanical tackle simulation studies, it appears that the impact in a frontal tackle imposes an anterior to posteriorly directed force on the thorax of the tackler and, with a fixed distal upper limb when grasping the ball carrier, can result in a relative anterior translation force on the humeral head (Seminati, Cazzola, Preatoni et al. 2017). Considering this mechanism of impact and the limitations of directly applying a passive pressure to the shoulder, it is feasible to consider a novel approach to illicit a translational force on the glenohumeral joint.

Joint position sense

Shoulder stability is dependent on optimal function of the static and dynamic stabilising systems, which is achieved by the combination of bony, capsuloligamentous and muscular systems (Janwantanakul, Magarey, Jones et al. 2001). Mechanoreceptors in the capsuloligamentous and muscular systems of the shoulder joint contribute to proprioceptive feedback (Myers and Lephart 2000, Lephart and Jari 2002). This inputs into the joint position sense (ability to identify the position of a limb) and kinaesthetic awareness (perception of active and passive motion) necessary for normal muscle coordination and timing, especially where active muscle forces play a significant role in shoulder joint stability (Janwantanakul, Magarey, Jones et al. 2001).

Multiple impacts during tackling and its effects on joint position sense have been studied in rugby players. The effect of simulated tackling on shoulder joint position sense was investigated in asymptomatic professional rugby players (n=22) to determine if a difference in joint position sense occurred at different ranges of motion (Herrington, Horsley, Whitaker et al. 2008). End of range (at 90º shoulder abduction and 80º shoulder external rotation) joint position sense was significantly reduced following repetitive tackles ($F=1.21$, $p=0001$). These findings suggest that repetitive stress to the shoulder from collisions can result in slackening of the shoulder joint capsule, leading to desensitisation of the neural receptors and consequently reducing shoulder joint stability at this position (Myers and Lephart 2000, Myers and Lephart 2002). Shoulder joint position sense was also evaluated in the shoulders of previously injured, non-injured and matched control group professional rugby players (n=45) (Herrington, Horsley and Rolf 2010). Eleven of the fifteen previously injured players had surgery of their shoulder injuries and returned to their sport however still showed significantly increased bilateral differences regardless of the testing angle ($p<0.002$). It was not determined whether these deficits were a result of injury or predisposed the player to injury. However, the researchers recognised the need for management options to restore these players' shoulder joint position sense. Considerations for training and conditioning sessions have been proposed to increase the shoulder's dynamic stabilisers resistance to fatigue (Morgan and Herrington 2014), but the incorporation of joint stabilisers (such as compression garments) to enhance proprioception remains unexplored in rugby.

Shoulder range of motion

The first study to evaluate rugby union players' (n=104; n=30, mean ± SD age 24.28±5.37 years old) shoulder rotational range of motion (ROM) identified that internal, external and total range of glenohumeral rotation was lower compared with healthy volunteers (Fernandez, Aravena, Verdugo et al. 2011). Decreased ROM may be associated with the frequency of tackling or the amount of weight training players participate in as part of their strength and conditioning regimes. As age was found to be a risk factor associated with external rotation ROM deficit (OR = 1.58, Confidence Interval (CI) 1.09 to 2.3, p= 0.016) while years of experience was a protective factor (OR= 0.63, CI 0.41 to 0.98, p=0.042), it led to the researchers taking an alternate view. The reduction in ROM could be the result of aging tissue changes or, alternatively, may be a mechanism protecting players from extreme end of ROM in vulnerable shoulder joint positions. These findings were corroborated in a recent study where 61% of professional rugby union players (n=91, mean ± SD age 20.8±2.9 years old) had "less than ideal or unsatisfactory" shoulder internal rotation ROM, while 84% of players external rotator (ER) ROM was non-ideal or unsatisfactory when compared bilaterally by the researchers (Bolton, Moss, Sparks et al. 2013). Adult professional rugby union players' (n=28, mean ± SD age 25±5.0 years old, range 19-41) shoulder range of motion was significantly different when compared to soccer players (n=22, mean ± SD age 23.5±4.8 years, range 18-33) (Horsley, Pearson, Green et al. 2012). Conditioning training carried out by professional rugby players and the sport itself could have accounted for the loss of glenohumeral internal rotation. Importantly, a cohort study of rugby league players found that those with a reduced range of shoulder internal rotation were significantly more likely to injure their shoulder (p=0.046), leading the authors to advocate for static stretching to improve internal rotation (IR) movement (McDonough and Funk 2014). This study shows that shoulder IR ROM deficits have been associated with shoulder conditions such as internal impingement and SLAP lesions, which warrants corrective interventions to address this imbalance. It is also noteworthy that most of the reviewed research has been conducted on adults highlighting a paucity of evidence around youth players. Further preventive research in the youth population would be advantageous in reducing their risk of injuries.

Posture

A high prevalence of abnormal thoracic posture (66% forward head posture, 60% thoracic spine khyphosis) was seen in a group of professional rugby players (n=91) evaluated using the New York Posture Test, compared to other literature on a non-sporting population (Bolton, Moss, Sparks et al. 2013). This may be due to muscle inflexibility as a consequence of over-emphasis of conditioning programmes on certain muscle groups such as the pectoralis major, and insufficient conditioning of the antagonist muscle, the latissimus dorsi (Haupt 2001). It is not clear how accurately this training observation was made and how generalizable the findings are to rugby, which warrants caution in interpreting their review. This postural adaptation is deemed to adversely impact scapular kinematics which may result in an increased risk of injury in rugby players. Subsequently, incorporating corrective exercises into an injury prevention programme may be beneficial in addressing this imbalance and reduce the risk of injury. It is not possible to determine if the imbalance is a sport-specific adaptation and is conducive to rugby; however, imbalances of this nature that are associated with injury are considered in other sports (Kibler, Ludewig, McClure et al. 2013, Hickey, Solvig, Cavalheri et al. 2018).

Scapular orientation and control

It is well established in the literature that the orientation and control of the scapula plays a significant role in shoulder function (Kibler 1998, Borsa, Timmons and Sauers 2003, Ludewig and Reynolds 2009, Kibler and Sciascia 2016). Anatomically, the scapula provides a stable base for the origin of the shoulder girdle muscles which facilitate optimal glenohumeral control. Normal shoulder biomechanics require a coordinated and synchronous relationship between the shoulder girdle and the glenohumeral joint. Dysfunction of the scapula to perform these roles can result in inefficient shoulder function and may lead to injury (Kibler 1998). Given the key role that the scapula plays in shoulder function, assessing the position and movement of the scapula is considered important by clinicians in the examination of the shoulder and to inform clinical management strategies (Hickey, Solvig, Cavalheri et al. 2018).

The gold standard method to accurately quantify scapular movement includes fluoroscopy and intercortical pinning however due to exposure to radiation, invasive techniques, equipment costs and time investment, there is a clinical need for a reliable and valid non-invasive method to measure scapular movement (Silverson, Cascia, Hettrich et al. 2019). Clinically, the scapula may be assessed using a range of methods in a static, semi-dynamic or dynamic position which consequently would contribute to methodological heterogeneity when evaluating the reliability of these tests. An initial systematic review found up to 54 assessment methods, measured either qualitatively or quantitatively, to evaluate the scapula (Larsen, Juul-Kristensen, Lund et al. 2014, D'Hondt, Kiers, Pool et al. 2017)). Overall, the static scapula position assessments had acceptable intra- and inter-rater reliability, with intraclass correlations (ICC) ranging from 0.61-0.99, kappa 1.00 and ICC 0.91-0.97, respectively. Similarly, the intra-rater reliability methods for semi-dynamic assessment had adequate levels ranging from ICC 0.64 – 0.98, though more varying results were observed for the inter-rater reliability. A wide range of reliability existed for dynamic scapula tests, from slight to almost perfect results. These authors concluded that visual observation and upward rotation measurement could be recommended to detect scapular dyskinesia in clinical practice. Recently, another systematic review found more than 30 tests used to assess the scapula, which were further defined as tests to measure the scapula's position and dynamic characteristics, and tests to diagnose impairment of the shoulder girdle (D'Hondt, Kiers, Pool et al. 2017). Due to diverse test procedures, poor methodological quality and overall fair to poor methodological quality, there were no specific reliable test measures for the scapula. These results conflicts with the earlier mentioned review and highlights that there is much variability with clinicians' ability to reliably detect dysfunctional scapula position and control. Nonetheless, there are studies that have evaluated the association between scapula motion and shoulder pain.

There is a body of evidence showing that there is an association between altered scapula motion and shoulder pain in overhead athletes (Santana, Ferreirar and Ribeiro 2009, Ellenbecker and Cools 2010, Kibler, Ludewig, McClure et al. 2013, Clarsen, Bahr, Andersson et al. 2014, Cools, Struyf, De Mey et al. 2014, Cools, Johansson, Borms et al. 2015, Kibler and Sciascia 2016, Hickey, Solvig, Cavalheri et al. 2018) and this association was also evident in elite rugby players (Kawasaki, Yamakawa, Kaketa et al. 2012). In a prospective cohort study the association between the incidence and relationship of scapular dyskinesis to shoulder discomfort was evaluated in 120 top level rugby players in Japan (Kawasaki, Yamakawa, Kaketa et al. 2012). Thirty-two percent of rugby players were identified with movement impairment of the scapula, which was significantly associated with a higher risk of reporting shoulder problems during a season (Odds Ratio = 4.4, 95% CI = 1.8 – 10.7, p=0.001) (Kawasaki, Yamakawa, Kaketa et al. 2012). These findings support the relevance of early screening in rugby players to determine if the presence of scapular dyskinesia can predict the occurrence of shoulder conditions during the season. Regardless if scapular dyskinesis is primary or secondary to shoulder pain, being able to reliably detect static or dynamic scapular dysfunction is considered a priority in the management of shoulder conditions (Ben Kibler, Uhl, Maddux et al. 2002, McClure, Tate, Kareha et al. 2009, Uhl, Ben Kibler, Gecewich et al. 2009, Kibler and Sciascia 2016).

Rotator cuff muscle strength

Another important modifiable injury risk factor is deficiencies in the strength of the shoulder rotator cuff muscles (Clarsen, Bahr, Andersson et al. 2014, Cools, Johansson, Borms et al. 2015), which has been identified in professional baseball players (Byram, Bushnell, Dugger et al. 2010) and elite handball players (Clarsen, Bahr, Andersson et al. 2014). In overhead athletes a rotator cuff imbalance of eccentric control of the external rotators over the concentric internal rotation strength (known as the functional deceleration ratio) is reported to increase stress on passive stabilisers and lead to detrimental translation of the humeral head (Berckmans, Maenhout, Matthijs et al. 2017). Yet, equivocal findings have been seen in rugby players (Edouard, Frize, Calmels et al. 2009, Ogaki, Takemura, Iwai et al. 2014, Ogaki, Takemura, Shimasaki et al. 2016). Edouard and colleagues carried out a cross-sectional study with 14 rugby players (national and regional playing level, aged 25 +/- 5 years) and 19 non-athletes to establish the rugby players' internal and external shoulder rotation isokinetic strength profiles (Edouard, Frize, Calmels et al. 2009). This study found that rugby practice did not influence any imbalances with the ratio of shoulder rotation muscle strength and is not likely a risk factor for injury. The mean values (mean peak torque ER/IR ratio in percentages) of the ER/IR ratio for the rugby players ranged from 0.63 to 0.67 (dominant side) and 0.65 to 0.73 (non-dominant side). The non-athletes' ER/IR ratio was 0.71 to 0.76 (dominant side) and 0.69 to 0.79 (non-dominant side). Moreover, most shoulder injuries occur during impact in the tackle and the role of muscle imbalances is not clear in traumatic injuries (Edouard, Frize, Calmels et al. 2009). In contrast, a prospective cohort study found opposing results in Japanese collegiate rugby union players (n=69) (Ogaki, Takemura, Iwai et al. 2014). Potential risk factors were assessed at preseason medical screening examinations and their association to subsequent shoulder injuries was examined. ER/ IR muscle strength ratio was one of three risk factors that were significantly associated with shoulder injury. An increase by 1.0 point in the ER/ IR strength ratio was associated with a 1.39 fold increase risk of shoulder injury in rugby players (95% CI, 1.08 – 1.77; p=0.00) (Ogaki, Takemura, Iwai et al. 2014). It should be pointed out that p should not have been reported as p=0.00 and should have been reported as p<0.001. They further acknowledged that the external rotation rotator cuff muscle strength ratio is important to be considered in the prevention of shoulder injury. The key difference between these studies is that Edouard et al. (2009) set out to determine the existence of a specific shoulder strength imbalance in a cross-sectional controlled study while Ogaki et al. (2014) using a prospective cohort study, evaluated risk factors in players who subsequently injured their shoulders playing rugby.

A further study was conducted by Ogaki et al. in a prospective study involving 28 collegiate rugby players to determine cut-off values for muscle strength for the assessment of shoulder injury risk. Collegiate players underwent preseason muscle strength tests and were followed for time-loss injury during the season. They found that the 1 repetition maximum (1RM) shoulder press ($p=0.01$; effect size, 1.00), shoulder IR ($p=0.03$, effect size, 0.65), ER ($p=0.04$, effect size, 0.67) and abduction ($p=0.01$, effect size, 1.00) isometric muscle strength were significantly lower in players who sustained an injury compared to non-injured players. Based on these results they concluded that maximal muscle strength of the shoulder rotator cuff muscles is more important than the muscle balance (Ogaki, Takemura, Shimasaki et al. 2016).

Acknowledging that the shoulder does not function in isolation is important when viewing upper limb movement. The relationship between grip strength and lateral shoulder rotation strength was assessed in 27 healthy participants using hand held dynamometry (Horsley, Herrington, Hoyle et al. 2016). A strong positive correlation between grip strength and the strength of the posterior rotator cuff muscles of the shoulder (lateral shoulder rotator muscles) ranged between $r=0.91$ ($r^2= 0.84$) and $r=0.72$ ($r^2=0.52$). The findings from this study suggest that the assessment of grip strength could provide information about rotator cuff muscle activation. Weakness of hand grip strength has been seen in patients with rotator cuff tears (Gotoh, Mura, Momonoi et al. 2002) and this relationship was also seen in patients following surgical repair of rotator cuff tears presenting with a decrease in grip strength at three months postoperatively (Goto, Tsuruta , Mura et al. 2005). These findings support a bi-directional relationship whereby grip strength is associated with shoulder strength and vice versa. A case in point is the effect that hand grip has on shoulder function. Investigators using fine wire electrodes in 16 healthy participants reported that a forceful hand grip task activated the supraspinatus and infraspinatus muscles in the shoulder (significant positive slope $p<0.01$) (Alizadehkhaiyat, Fisher, Kemp et al. 2011). It is well established that the rotator cuff muscles provides dynamic stability to the glenohumeral joint (Inman, Saunders and Abbott 1996, Wilk, Arrigo and Andrews 1997, Wuelker, Korell and Thren 1998), and in a sport like rugby where repeated impacts to the shoulder may compromises the functional stability provided by these muscles (McCarty, Ritchie, Gill et al. 2004), the assessment of grip strength could be important to evaluate the integrity of the rotator cuff muscles alongside shoulder conditions.

Using stage two of the TRIPP model, a number of aetiological factors associated with the cause of shoulder injuries in rugby have been identified that may lead to countermeasures being developed in the next stage. Preventative interventions that are designed to target these risk factors warrant evaluating to determine their part in the strategy to reduce the burden of shoulder injuries in rugby.

Preventative measures

The first of the sport injury prevention frameworks was published nearly three decades ago calling for preventative measures to reduce the risk of injury, yet it was not until recently, in 2016, that a staged framework was proposed describing the process about how to develop preventative strategies (Donaldson, Lloyd, Gabbe et al. 2016). It calls for expert clinicians and practitioners input during the consultation and development stages of the intervention. A bottom up approach that seeks feedback about the acceptability of the strategy from stakeholders and end users is also recommended during this process (Hanson, Allegrante, Sleet et al. 2014). Next, evaluating the intervention against a relevant theory is recommended to enhance the possibility of it being adopted and maintained (Hanson, Finch, Allegrante et al. 2012). Delivery agents and end users should provide feedback allowing for amendments prior to evaluating the intervention.

There have been a range of injury prevention strategies introduced in rugby, such as law changes to engagement at the scrum (Cazzola, Preatoni, Stokes et al. 2014, Preatoni, Cazzola, Stokes et al. 2016) and the removal of dangerous tackles from the game (Cross, Tucker, Raftery et al. 2017). Consequently, reductions in catastrophic injuries (Reboursiere, Bohu, Retiere et al. 2016) and a significant reduction in injuries at the scrum (England Professional Rugby Injury Surveillance Project Steering Group) have been reported. A further approach to injury prevention and player safety from sport governing bodies has been through educational programmes such as Rugby Smart and Bok Smart programmes in New Zealand and South Arica, respectively. Notably, the risk of spinal injury and scrum-related injuries were reduced by 54% and 89% after the Rugby Smart programme was introduced (Quarrie, Gianotti, Hopkins et al. 2007). A further study reported that better player safety awareness during match events was evident (Gianotti, Quarrie and Hume 2009). Similarly, the Bok Smart programme was deemed to have influenced positive changes in players' behaviours with a reduction in catastrophic injury by 40% (Brown, Verhagen, Knol et al. 2016). These results suggest that disseminating an education programme to coaches and officials on injury prevention is one component that can have important changes to players' safety behaviours and reduction of injury risk.

Lycra compression sleeve

There have been a number of different types of protective wear used amongst players to reduce shoulder injuries. The use of compressible foam material designed according to World Rugby regulations has been used in shoulder pads aimed at reducing the impact force to the shoulder. An associated reduction of 40% in localised force over the acromioclavicular joint was seen during the tackle in laboratory studies (Pain, Tsui and Cove 2008). Other researchers found that shoulder pad performance needed to be improved to afford better protection to the shoulder (Harris and Spears 2010, Usman, McIntosh and Frechede 2011). Further still, a similar incidence of shoulder injuries was reported for those who wore shoulder pads (9.6 per 1000 hours; 95% CI, 7.4 to 11.8) compared to those without (9.6 per 1000 hours; CI, 7.2 to 12) (Headey, Brooks and Kemp 2007). As a result of the findings from these studies, the benefit of using shoulder pads remains unclear. Other joint stabilisers such as compression sleeves are popular in sport, yet their effects on shoulder function in rugby players are unknown.

There is an absence of literature describing the effects of an upper limb compression sleeve used in a sport rehabilitation context, which necessitates a broader evaluation of the role of joint stabilisers to understand its potential benefits. Other types of joint stabilisers, such as taping, have shown effects on shoulder internal and external rotation in athletes with diagnosed shoulder instability (McConnell, Donnelly, Hamner et al. 2011). Uninjured overhead athletes (n=26) increased their range of motion (ROM) (p=0.02) while those athletes who had a previous history of injury decreased their ROM (p=0.003). It was postulated that taping may reduce the anterior humeral head translation by its effects on muscle activity and improved shoulder kinematics in athletes returning to sport following injury. Increases in shoulder rotational ROM in asymptomatic athletes may be due to the application of tape correcting the centre of the axis of rotation which may be altered with repetitive overhead activities (McConnell, Donnelly, Hamner et al. 2012). The application of the tape according to this study protocol is not viable for self-administering by all athletes because the tape must be anchored to the posterior part of the upper mid-thoracic region. Moreover, the tape is single-use and requires reapplication for each sport session. Conversely, a lycra compression sleeve is relatively easy to don and can be used multiple times, offering better use than tape in this instance.

Implementation research

Evidence-based neuromuscular warm up routines are efficacious at reducing sport injury risk (Aaltonen, Karjalainen, Heinonen et al. 2007, Lauersen, Bertelsen and Andersen 2014, Emery, Roy, Whittaker et al. 2015, Taylor, Ford, Nguyen et al. 2015) however all suffer from poor uptake of the program across all sports. Once preventative measures have demonstrated efficacy, research into implementation issues needs to be considered to adequately describe how to achieve injury prevention that is acceptable, adopted and adhered to by the targeted sporting population (Finch 2006). A crucial step forward for successful sport injury prevention in the real-world is understanding the role of behaviour in injury risk, though this remains an under-researched area in the literature of this nature. In a review of 100 articles in the sport injury prevention context, only eleven of the included studies had an applied or established behavioural change model with only four of those eleven studies formally testing a theory-driven hypothesis (McGlashan and Finch 2010). Research on the use of behaviour change theories in coach development programmes also found that behaviour change theories was used infrequently and inconsistently in 29 studies in a recent review (Allan, Vierimaa, Gainforth et al. 2018). Though there is a paucity of evidence in this area, there is growing recognition of the role behaviour change theory can play in interventions designed to promote behaviour change in the field of sport injury prevention (Verhagen, van Stralen and van Mechelen 2010, Allan, Vierimaa, Gainforth et al. 2018). Before actual injury prevention is achieved, the determinants and influences of sports safety behaviour need to be understood to enable appropriate and achievable intervention goals to be set (Finch 2011).

The majority of behaviour change theories that were used in the aforementioned reviews (McGlashan and Finch 2010, Allan, Vierimaa, Gainforth et al. 2018) used motivational frameworks which focuses on the underlying motivational factors behind an intention to perform a health behaviour or avoid a risk behaviour (Armitage and Conner 2000). This view implies that motivation is sufficient for successful behaviour change, however critics of this approach argue that it does not account for the poor correspondence between motivational variables and subsequent behaviour. In view of the limited application of behavioural theory in sport injury prevention, there is scope for additional research in this area to facilitate behaviour change at the individual and team level (McKay, Merrett and Emery 2016).

Considering that injury prevention interventions need to be adopted by the target audience for them to be effective, the Health Action Process Approach (HAPA) is a health behaviour model that is suited to describe the adoption of preventive behaviours. The HAPA model proposes that adoption, initiation and maintenance of health behaviour is a process consisting of two phases: a motivational phase and a volitional phase. The motivational phase is characterised by individuals forming a behavioural intention, and is followed by the volitional phase where intenders plan to enact and engage with the required behaviour. The motivational phase is underpinned by task self-efficacy and outcome expectancies which are predictors of intention, with risk perception viewed as a distal factor. In the volitional phase, importance is placed on translating intention into behaviour through action and coping plans, which once initiated, are then aided by task and maintenance self-efficacy. This behaviour can then be influenced by environmental barriers and facilitators that can promote or inhibit the behaviour.

The HAPA model has been evaluated in female youth soccer players (n=10 coaches, n=200 players aged 12 to 16) shown to be appropriate to predict intention to use a neuromuscular training programme to reduce the risk of injury (McKay, Merrett and Emery 2016). The HAPA model is more suited to use in real-world sport injury prevention as it goes beyond just the motivational factors, focusing on the proximal factors of behaviour (eg: action, coping planning and maintenance self-efficacy). This model offers a further step to other health behaviour models (e.g., Theory of Planned Behaviour) by including factors that relate to maintenance of health behaviours which is necessary for sustaining injury prevention behaviours. Through this approach, it is possible to understand the underlying determinants of intention and adoption of safety behaviours in sport injury research. Identifying these proximal factors to adopting and maintaining safety behaviours such as preventive exercise interventions will allow the HAPA model to further research beyond the motivational phase of the model.

Many factors combine to influence individual players' behaviour within a team and club setting, which ecological research models in general aim to overcome by focusing attention on the social and environmental causes of behaviour and to identify interventions to target these (Verhagen and van Mechelen 2010). In ecological models' interactions between people and their social and physical environment results in that individual's behaviour. The assumption of this model is that for behaviour change to be adopted and sustained, it needs to be supported and encouraged by the social and environmental influencers in which they operate (Verhagen and van Mechelen 2010). The influencers of a shoulder injury prevention intervention in rugby will depend on the level at which it is specifically being targeted. Community youth rugby is delivered through a multi-level, hierarchical structure that needs to be considered when implementing an intervention. Injury risk management strategies are often driven by those at higher levels of the sport hierarchy which may or may not lead to implementation of relevant practice at lower levels (Finch and Donaldson 2010). At the club level, organisational infrastructure, strategic policy, administrative factors and the attitudes and knowledge of key personnel require consideration for implementation to be successful.

The role of the coach within a team is recognised as a pivotal factor in the delivery of the safety intervention and player adherence largely influences the success of these programmes (Finch and Donaldson 2010, Finch, Diamantopoulou, Twomey et al. 2014, White, Otago, Saunders et al. 2014). The attitude and knowledge of the coaches is also considered an important influencer in the implementation of sport safety strategies.

From 2008 to 2012, Brown et al. (2016) conducted a cross-sectional study using a questionnaire (knowledge, attitude and behaviour) to assess whether injury prevention behaviours were associated with coach-directed education in South African rugby players (n= 2279 junior and n=1642 senior players). Injury prevention education from coaches was associated with corresponding behaviours in these players. Coaches were recognised as the preferred source of rugby injury prevention content such as rugby technique, acknowledging them as influencers of player behaviour in rugby. The majority of players preferred to receive education about warming up routines from physiotherapists (Brown, Gardner-Lubbe, Lambert et al. 2016). This study highlights that players' behaviours, in relation to injury risk, is influenced by multiple behavioural influencers such as the coach and physiotherapist who are in key roles to drive educational interventions in rugby injury prevention. For example, utilising physiotherapists in this cohort of players, to advocate the use of efficacious injury prevention exercise programmes is recognised as an indirect pathway to influence players' injury risk behaviour (Verhagen, van Stralen and van Mechelen 2010). In an under-resourced community sport context where there is no access to physiotherapy services, there is a greater reliance on the coach as the source of injury prevention strategies. It is important that implementers of rugby injury prevention recognise that these delivery agents are integral to optimise the overall impact of their preventative intervention.

Further evidence from a systematic review supports education of coaches and referees to changing athletes' behaviours resulting in reducing athletes' risk of concussion in rugby (Fraas and Burchiel 2016). The Rugby Smart Concussion Management Education Programme was evaluated by using concussion/ brain injury claims made to the Accident Compensation Corporation in New Zealand in 2003-2005. As part of the education programme coaches were issued with side-line concussion check cards, and coaches and referees (from under six age group to senior adults) were required to attend a RugbySmart workshop and watch a concussion management video. A 10.7% reduction was found over the course of a two-year period in concussion/ brain injury claims filed with the Accident Compensation Corporation (Gianotti and Hume 2007). The important role that rugby coaches have in the communication of injury prevention and attitudes to player safety is supported by other studies that investigated programme effectiveness and changes in injury prevalence in junior South African rugby players (n=2279, under 18 years old) (Brown, Gardner-Lubbe, Lambert et al. 2015) and in New Zealand (Chalmers, Simpson and Depree 2004). Considering the high-risk of injury associated with the tackle, a recent study used a questionnaire to further highlight the coaches' influence on rugby players' attitudes towards injury prevention and performance in the tackle (nine under 19 rugby teams) (Hendricks, den Hollander and Lambert 2019). A positive association [X^2 = (df 16, N=159) 29.13, p=0.023, Cramer's V=0.21, moderate] was found between the amount of time coaches spent educating players (verbal instruction) about proper tackling technique for injury prevention with how important players rated the respective tackle training objective. Coaches however did not feel comfortable with identifying technical deficiencies and providing technical demonstrations of the tackle which supports the need for rugby injury prevention programmes to include practical coaching components. The use of education resources and coaching clinics was most influential of players tackling technique for injury prevention and performance. Coaches play a profound role in shaping athletes experiences and are often targeted in interventions to enhance athlete outcomes such as sport injury prevention.

Valuable advice about what may work best and is most feasible, affordable and sustainable can be gained from researchers working in tandem with practitioners, policy makers and the target community (Hanson, Allegrante, Sleet et al. 2014). This consultation will yield a clearer understanding about the political, social and environmental factors that are specific to community youth rugby. In recent UK government plans, rugby union was selected as one of five sports to focus on increasing its prominence of competitive sport in schools in England, which has raised some concerns about the safety of the game (Freitag, Kirkwood and Pollock 2015). In light of this sport strategy from the UK government there is a need to ensure the safety of youth rugby is evaluated as a duty to protect children from the risk of injury. The government intends to put links in place between schools and rugby union organisations, which illustrates the need for a mutually supportive collaboration to be developed in the implementation process (Chalmers, Simpson and Depree 2004). Being aware of the government plans for rugby in the UK is of strategic importance when implementing safety strategies and ensuring player welfare.

Summary

Shoulder injuries have been shown to be amongst the most common injuries reported in rugby across all playing levels, irrespective of the injury definition used, and they account for the greatest number of days absent from match play. This review has identified a need to further analyse the characteristics of shoulder injuries in rugby using consistent methodologies as outlined in the consensus statement for rugby injury surveillance to inform evidence-based countermeasures. The dearth of evidence on shoulder injury epidemiology in community rugby justifies the need to address this gap in the literature to allow for the magnitude of the problem to be described. The impact of shoulder injuries is considerable and extends beyond the physiological level, threatening players' lifelong sport participation and stakeholders which merits investigation.

Conflicting research exists on the association of some risk factors and shoulder injuries such as shoulder rotation range of motion and shoulder rotation strength, but it is less clear how well clinicians and practitioners are able to assess them. Identifying modifiable risk factors to these shoulder injuries partly depends on the availability of reliable shoulder tests, however the evidence in this regard is inconsistent and merits further investigation in rugby players. A key omission in the literature has been a lack of a focused intervention aimed at reducing the risk of shoulder injuries in rugby players, which is an under-investigated feature of existing injury prevention measures. To move rugby injury prevention beyond descriptive and analytical research requires the development of interventions that are adopted and sustained in the real-world. Outlining the development process of a preventive shoulder-specific warm up routine in community youth rugby provides evidence to an area where there is limited research to guide the advancement of injury prevention interventions. Testing the feasibility and acceptability of the shoulder-specific warm up routine while considering practical methods of injury surveillance is important to provide new knowledge that helps this research field to understand how to translate research into practice. Other interventions such as a lycra compression sleeve have shown beneficial results in other populations, however never been tested in rugby players and offers a novel research opportunity.

Chapter Three

Shoulder Injuries in English Community Rugby Union

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Introduction

Rugby union is a sport that involves full contact between players of opposing teams and in each match there are numerous occasions of high-impact collisions. Players wear very little protective equipment or padded clothing compared with sports of a similar nature, such as American Football (Helgeson and Stoneman 2014). Due to the nature of the game and characteristics of players, the risk of sustaining an injury across all levels of Rugby Union appears to be relatively high (Roberts, Trewartha, England et al. 2013, Williams, Trewartha, Kemp et al. 2013), although comparable with other full contact sports.

A study of time-loss injuries (>8 days severity) in English community level rugby union reported the incidence of shoulder injuries to be second only to knee injuries, with an incidence of 2.3 injuries per 1000 hours with a mean severity of 9.3 weeks missed (Roberts, Trewartha, England et al. 2013). In addition, approximately 40% of rugby union players in the premier league in South Africa were found to have primary shoulder injury (Lynch, Lombard, Coopoo et al. 2013). The shoulder joint is the joint with the highest risk of dislocation during sports and the injury burden associated particularly with dislocations and subluxations can result in impairment and a significant absence from competition (Headey, Brooks and Kemp 2007, Brooks and Kemp 2008, Usman, McIntosh, Quarrie et al. 2014, Bohu, Klouche, Lefevre et al. 2015). Lee and colleagues also recognised that sustaining a rugby injury was one of the predominant reasons for players ceasing to continue playing rugby (Lee, Garraway, Hepburn et al. 2001). Rugby players are therefore at risk of ceasing to take part in the sport if they are to sustain a significant shoulder injury. There is still relatively little information about the specific nature of shoulder injuries sustained due to rugby participation in the large amateur playing base, in terms of types, risk factors, mechanisms, and therefore little evidence to inform injury prevention initiatives, rehabilitation, and coaching strategies. The specific aim of this study was to describe the incidence, severity and type of shoulder injuries resulting from match play in adult community rugby union between 2009 and 2013.

Materials & Methods

Participants

Invitations to participate in the study were sent to English adult community-level clubs who were competing in the Rugby Football Union (RFU) league structure (levels 3 – 9) (Rugby Football 2015). The study was conducted over four seasons between 2009 and 2013 in a sample of these clubs who agreed to participate (2009/10, n=46 [61 clubs at the beginning of the season]; 2010/11, n=67 [90 clubs at the beginning of the of the season]; 2011/12, n=76 clubs [104 clubs at the beginning of the of the season]; 2012/13, n=50 clubs [106 at the beginning of the of the season]). A total of 239 club-seasons made up the final sample. The participating clubs were sub-categorised into: RFU level 3 and 4, made up largely of 'semi–professional' players; RFU level 5 and 6, made up largely of 'amateur' players; and RFU level 7, 8 and 9, made up largely of 'recreational' players. Players were given information about the study and could opt-out from participation by informing the club medical staff who omitted details on that player. The study had institutional ethics approval from the University of Bath (EP 09/10 9) and the procedures met the ethical standards of the journal (Harriss and Atkinson 2015).

Time – loss injuries

Standard injury report forms were completed and returned by injury management staff (with a physiotherapy, sport rehabilitation or sport therapy qualification as a minimum) working at the clubs taking part. Any shoulder injury sustained during a first team match resulting in an absence from participation in match play for one week or more from the day of injury was defined as a "time – loss" shoulder injury. The return to play date was the date of the match on which the player was considered fit for selection, and severity was defined by the number of weeks missed. The consensus statement on injury definitions in rugby union describes the least severe injuries collected in this study as 'moderate' (8 – 28 days absence) (Fuller, Molloy, Bagate et al. 2007).

Injuries were recorded according to the type, injury event, playing position, time in match, and severity for all time-loss injuries. The Orchard Sports Injury Classification System (OSICS) version 8 (Rae and Orchard 2007) was used to categorise the type of injury by the injury management personnel in discussion with the player. Only injuries that were diagnosed on the OSICS starting with "S" (denoting the shoulder site) were included in this analysis. Injuries incurred through any activity other than rugby match play (including rugby training) were not included in the analysis. The definition used for recurrent injuries was that an injury was recorded to be of the same type and to the same body location as an index injury (Fuller, Molloy, Bagate et al. 2007).

Medical Attendances

During seasons 2009/10, 2010/11 and 2011/12, the injury management staff also recorded information each time during a match that a medical attendance was made relating to the shoulder region using the Orchard Sports Injury Classification System.

Data Analysis

Playing positions were grouped as forwards and backs then sub grouped into front row (props and hooker), second row (locks), back row (number 8 and flankers), inside backs (scrum half and fly half), midfield backs (centres) and outside backs (wings and full back). Match exposure was determined by the number of matches x number of players per team x match duration (hours) (Fuller, Molloy, Bagate et al. 2007). The incidence and severity of injuries per season were calculated, with injury incidence documented as the number of medical attendances or time-loss injuries per 1000 player hours of match exposure; severity was represented as mean and median values, and 95% Poisson confidence intervals (CI) for outcome variables were calculated. Differences between groups were determined using a two-tailed Z test for comparison of rates. Differences were deemed to be statistically significant if $P \leq 0.05$.

Results

Incidence and severity of time-loss shoulder injuries

A total of 116740 hours of match exposure was recorded. From this exposure, 254 time-loss shoulder injuries were reported, with an overall incidence of 2.2 per 1000 hours (95% CI: 1.9 to 2.4) and a mean injury severity of 9.5 weeks missed (95% CI: 8.2 to 10.8)

Table 4). The semi-professional group had an incidence of 2.8 injuries per 1000 hours (95% CI: 2.2 to 3.5), which was higher than the recreational group at 1.8 injuries per 1000 hours (95% CI: 1.4 to 2.2, $p=0.004$). There was a significant increase in incidence during the 2012/13 season for all groups combined, with 3.5 injuries per 1000 hours (95% CI 2.7 to 4.2) compared with all previous seasons (2009/10: 1.7 injuries per 1000 hours, 95% CI 1.1 to 2.2; 2010/11: 2.1 injuries per 1000 hours, 95% CI 1.6 to 2.6; 2011/12: 1.7 injuries per 1000 hours, 95% CI 1.3 to 2.1, $p < 0.05$).

	Matches	Match Hours	Number of injuries	Injury Incidence per 1000 hours (95% CI)	Mean Severity in Weeks (95% CI) [Median]
All	5837	116740	254	2.2 (1.9 to 2.4)	9.5 (8.2 to 10.8) [6]
Semi-Professional	1335	26700	76	2.8 (2.2 to 3.5)*	9.7 (8.4 to 11.0) [5]
Amateur	2134	42680	93	2.2 (1.7 to 2.6)	9.5 (8.2 to 10.8) [5]
Recreational	2368	47360	85	1.8 (1.4 to 2.2)	9.2 (8.0 to 10.4) [6]

* Significantly higher than ‘recreational’

Table 4: Match exposure, overall shoulder injury incidence and severity

Injury type

The incidence of acromioclavicular joint injury for semi-professional players was 1.2 per 1000 hours (95% CI: 0.8-1.6); which was significantly greater than the incidence of this injury type in recreational players (0.5 per 1000 hours, p=0.002 (95% CI: 0.3-0.7) (Table 5). Shoulder sprains and dislocations was the main injury type for recreational players (0.8 per 1000 hours (95% CI: 0.6-1.1)). The most severe injuries that were reported were arm fractures resulting in a mean of 17.6 weeks missed.

Injury Type	Number of Injuries	Incidence (95% CI)				Mean Severity All (95% CI) [median]
		Semi-Professional	Amateur	Recreational	All	
Haematoma	3	0(0-0.1)	0(0-0.1)	0(0-0.1)	0.01 (0-0.1)	4 (3.5-4.5) [4]
Sprains and dislocation	99	0.9(0.6-1.3)	0.8(0.5-1.1)	0.8(0.6-1.1)	0.8 (0.7-1.0)	10.7(9.3 – 12.1) [6]
Acromioclavicular joint injury	87	1.2(0.8-1.6)*	0.8(0.5-1.0)	0.5(0.3-0.7)	0.7 (0.6-0.9)	7.5(6.5 – 8.5) [6]
Tendon injuries	27	0.3(0.1-0.5)	0.2(0.1-0.3)	0.2(0.1-0.3)	0.2 (0.1-0.3)	12.6(10.9-14.3) [7]
Fracture arm[3]	19	0.1(0-0.3)	0.1(0-0.3)	0.2(0.1-0.3)	0.2 (0.1-0.2)	17.6(15.3-19.9) [14]
Other injury[4]	19	0.3(0.1-0.5)	0.2(0.1-0.3)	0.1(0-0.1)	0.2(0.1-0.2)	3.6(3.1-4.1) [3]

*Significantly higher than recreational

Table 5: Type and Severity of Match Shoulder Injuries

Injury event

Contact mechanisms accounted for 99% of the shoulder injuries with the remaining 1% comprising non-contact injuries (n=4) resulting from try scoring attempts (Table 6), therefore possibly due to contact with ground rather than other players. Tackling was associated with the highest proportion of all shoulder injuries (48%) as well as being associated with the highest proportion of shoulder sprain and dislocation injuries (56%) and acromioclavicular joint sprain injuries (44%).

[3] Fracture arm accounts for fractured clavicle (n= 16), proximal humeral fractures (Hill-Sachs lesion n=2, fracture neck of humerus n=1).
[4] Other injury accounts for shoulder and arm neurovascular n=9 and upper arm muscle strains n=10.

Injury Event	All injuries (n = 254)	Incidence of All Injuries (95% CI)	Diagnosis[5]						Mean Severity (weeks missed) (95% CI) [Median]
			Hematoma (n=3)	Sprains and Dislocation (n=99)	Acromioclavicular joint injury (n=87)	Tendon injuries (n=27)	Fracture Arm (n=19)	Other injury (n=19)	
All Tackled	84	0.72(0.57-0.87)	2	25 (25%)	34 (39%)	9 (33%)	9 (47%)	5(26%)	10.3(8.9 - 11.7)[7]
Tackled	79		2	25	32	9	7	4	
Tackled collision[6]	5				2		2	1	
All Tackling	121	1.04(0.85-1.22)	1	56 (56%)	39 (44%)	14 (52%)	5 (26%)	6 (32%)	9.2(8-10.7)[5]
Tackling	118		1	55	38	13	5	6	
Tackling collision	3			1	1	1			
Ruck/ maul	26	0.22(0.14-0.31)		7 (7%)	11 (13%)	1 (4%)	2 (11%)	5 (26%)	9.0(7.8-10.2)[7]
Collapsed maul	4			1	3				
Scrum	10	0.09(0.03-0.14)		4 (4%)	2 (2%)	2 (7%)	1 (5%)	1 (5%)	6.7(5.8-7.6)[3.5]
Collapsed scrum	1							1	
Lineout	1	0.01(0-0.03)		1 (1%)					24[24]
Collision	4	0.03(0-0.07)		2 (2%)		1 (4%)	1 (5%)		11.0(9.5-12.5)[3.5]
Non – contact[7]	4	0.03(0-0.07)		3 (3%)			1 (5%)		15.5(13.4-17.6)[16]
Unknown	4	0.03(0-0.07)		1 (1%)	1 (1%)			2 (11%)	2.5(2.2-2.8)[2.5]

Table 6: Injury diagnoses of shoulder injuries sustained during matches with the associated match events

[5] The number of injuries for each event has been represented as a percentage of the total number of injuries for that diagnosis
[6] A tackled collision was when a tackler stops the progress of the ball carrier without the use of his arms (illegal tackle).
[7] These injuries may have been due to contact with the ground.

Recurrences

A total of 27% of the shoulder injuries were reported by medical staff as being recurrent injuries (same location and same type of injury). Shoulder sprain and dislocation had a relatively high rate of recurrence at 36%. The mean severity of new (index) and recurrent injuries was 8.7 and 12.2 weeks missed, respectively. Arm fracture resulted in the highest severity of injuries, 15.0 weeks missed for new injuries and 30.7 weeks missed for recurrent fracture injuries (Table 7).

Injury Type	Number of Injuries	Proportion, %		Mean Severity, weeks (median)	
		New	Recurrent	New	Recurrent
Haematoma	3	100	-	4.0 (4.0)	-
Sprains and Dislocation	99	64	36	9.0 (5.0)	14.0(6.0)
Acromioclavicular joint injury	87	80	20	7.6 (6.0)	7.4 (6.0)
Tendon injuries	27	70	30	12.7 (7.5)	12.4 (4.0)
Fracture arm	19	84	16	15.0 (14.0)	30.7(29.0)
Other injury	19	79	21	3.9 (3.0)	2.5 (2.5)
All injuries	254	73	27	8.7 (6.0)	12.2 (6.0)

Table 7: Proportion and severity of 'New' and 'Recurrent' injuries

Playing position

The incidence of match shoulder injuries was the same between forwards and backs at 2.2 (95% CI: 1.8-2.5, n=134) and 2.2 (95% CI: 1.8-2.6, n=120) injuries per 1000 hours, respectively (Figure 4). Overall, back row players sustained the highest incidence of all shoulder injuries for a given playing position (2.9 injuries per 1000 hours), which was significantly higher than that for second row players (1.2 injuries per 1000 hours, p=0.001). Back row players also sustained significantly more acromioclavicular joint injuries with 1.3 injuries per 1000 hours (95% CI: 0.8 to 1.7) when compared with the incidence for second row at 0.2 injuries per 1000 hours (0 to 0.4) (p= 0.002).

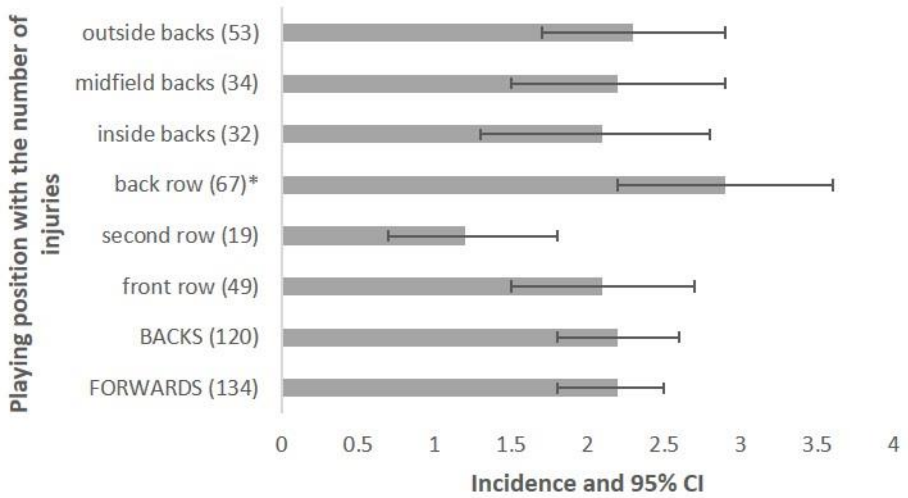

Figure 4: Distribution of shoulder injuries as a function of playing position

Timing within Game

Injury incidence was not different across match quarters: 1.6 injuries per 1000 hours (95% CI: 1.2 -2.1) in the first quarter, 2.2 injuries per 1000 hours (95% CI: 1.7 – 2.7) for the second quarter and third quarters, and 2.3 injuries per 1000 hours (95% CI: 1.8 – 2.9) for the fourth quarter. The mean injury severity was significantly lower in the first quarter (5.9 weeks missed, 95% CI: 4.2 – 7.6) than all other quarters (second quarter: 11.1 weeks missed, 95% CI: 8.7 – 14.4; third quarter: 9.1 weeks missed, 95% CI: 6.8 – 11.3; fourth quarter: 9.5 weeks missed, 95% CI: 7.3 – 11.8).

Medical Attendances

The incidence of medical attendances over 3 seasons for shoulder injuries was 23.1 attendance injuries per 1000 match hours (95% CI: 22.1-24.1), in the context of 229.3 attendance injuries per 1000 match hours (95% CI: 226.23-232.39) for all injuries. Medical attendance for shoulder injuries equated to an incidence of 1 shoulder medical attendance for every 2.2 team games. The incidence of medical attendances for shoulder injuries was significantly higher for semi - professional players (29.1 injuries per 1000 hours) than that of recreational (21.8 injuries per 1000 hours, $p < 0.001$) and amateur players (20.5 injuries per 1000 hours, $p < 0.001$).

Discussion

These findings on match-play shoulder injuries have implications for the healthcare and conditioning specialist in relation to shoulder injury prevention and rehabilitation in addition to coaching proper tackling technique. Medical attendance for a shoulder injury was one in every 2.2 team games, whereas the incidence of shoulder injuries resulting in more than 8 days of time loss was 2.2 per 1000 hours, which is approximately one injury every 22 team games. Collectively, this injury trend and the mean severity of time loss injuries of 9.5 weeks missed informs the initial stage of the sport injury prevention model, to highlight the scale of the problem. Particular initiatives should be directed to interventions with the semi-professional players who had the highest incidence of shoulder injuries (both time-loss and medical attendance), which was significantly greater than recreational players, specifically for acromioclavicular joint injuries. Furthermore, the specific positional demands of back row players must be taken into consideration in order to address the higher incidence of shoulder injuries sustained by these players, and this may involve specific injury prevention strategies for these positions.

Overall the higher level of competition (semi-professional) presented with a significantly higher incidence of shoulder injuries than the recreational level, but this is lower than reported for professional players for missed matches (4.3/1000 hours) (Headey, Brooks and Kemp 2007). The higher incidence of injuries amongst the semi-professional playing level is in accordance with previous studies that injury incidence increases at higher playing levels (Roberts, Trewartha, England et al. 2013). The injury risk for higher playing levels has been proposed to be due to there being a higher match play intensity, skill and fitness attributes which manifests in a greater number of contact events and more force in impacts (Roberts, Trewartha, England et al. 2013). Higher playing levels have also been shown to have an increase in the proportion of active shoulder tackles than lower playing levels (13% in younger than 15 years old to 31% in elite players) increasing the risk of tackle related injuries (McIntosh, Savage, McCrory et al. 2010). A recent study of upper limb injuries carried out over five rugby seasons also found a higher incidence of shoulder injury of 8.6 per 1000 hours than other upper limb injuries (Usman and McIntosh 2013). Surprisingly this is accounted for due to the inclusion of Colts players (under 20 year old) who presented with the highest incidence of shoulder injuries in the group which is contrary to injury trends elsewhere (Palmer-Green, Stokes, Fuller et al. 2013). Usman and McIntosh (2013) proposed that younger players are thought to be at a relatively higher risk as they are transitioning from school playing level to higher levels of competition. At this stage, players may have developed a faster running speed and strength but these younger players lack experience, skills and fitness to go with these physical developments, which may contribute to an injury risk. It is plausible that these factors may have influenced the higher incidence in their study.

Contact injuries accounted for 99% of the shoulder injuries in this study with the tackle event accounting for the vast majority, of which the tackler had the highest proportion of shoulder injuries. Injury analysis elsewhere is in agreement that the tackle is the leading cause of shoulder injury (Horsley, Fowler and Rolf 2013, Williams, Trewartha, Kemp et al. 2013, Usman, McIntosh, Quarrie et al. 2015). Coaching of correct and successful tackle technique is based on the analysis of proficiency between injury and non-injury tackle events. Prior to contact, tacklers should shorten their steps while their head position is up and forward facing to the ball carrier. Both tackler and ball carrier should train to heighten their peripheral vision to adapt better to the environment. The tackler should stay square to the ball carrier and make contact with the mid-torso of the opponent using their shoulder and driving with their legs. This point of contact is suggested as there is a greater risk of injury to the tackler when contacting the ball carrier low. Post-contact requires the tackler to drive the legs, use the shoulder and arms to wrap or pull (Fuller, Ashton, Brooks et al. 2010, Hendricks, Matthews, Roode et al. 2014, Burger, Lambert, Viljoen et al. 2016).

Shoulder sprains and dislocation were the highest incidence for all groups accounting for 0.8 per 1000 hours, which was also most prominent in research by Lynch et al. (2013) which analysed the incidence of shoulder injuries in rugby union players participating in the premier league in South Africa. Detailed video analysis of injury mechanisms has recognised that the suboptimal glenohumeral joint alignment and poor technique of the tackler are expected risk factors for shoulder dislocation (Longo, Huijsmans, Maffulli et al. 2011). Moreover, the magnitude of force to the tackler’s shoulder is substantial and up to approximately 2000 N during a tackle (Usman, McIntosh and Frechede 2011). Players therefore need to be better conditioned to optimise their glenohumeral joint position in preparation for the impact forces and consider tackling technique factors that may be associated with the occurrence of this injury type (Gianotti, Quarrie and Hume 2009). Attention should be targeted to train the neuromuscular control that is required for the player to adopt the optimal tackling position (Horsley and Herrington 2014). This particularly involves the glenohumeral and scapulathoracic dynamic neuromuscular control that is required to achieve the ideal shoulder position for the tackle (Morgan and Herrington 2014). The integrity of the glenohumeral joint and its capsuloligamentous support is under maximum strain when the joint is under load at the end of its range of motion (Lephart and Jari 2002). Neuromuscular control of the shoulder therefore needs to be effective during a tackle for players to avoid reaching the vulnerable end range of motion in order to reduce the risk of shoulder dislocation / instability.

The incidence of acromioclavicular joint injury for semi–professional players was higher than the lower playing levels. The higher number of tackles made by the semi-professional players than lower playing levels in addition to a greater risk of injury per 1000 tackle events could explain the higher incidence of acromioclavicular joint injury for semi–professional players (Roberts, Trewartha, England et al. 2014). Similarly, McIntosh et al. (2010) has demonstrated that the higher number of tackles at this level increases the risk of injuries, which is in support of our findings in this study. Research findings from studies carried out in England and Wales and from the Super Rugby matches in the southern hemisphere concur that acromioclavicular joint injury was also amongst the most common shoulder injuries incurred by professional players (Brooks and Kemp 2008, Usman, McIntosh, Quarrie et al. 2015). During the tackle, when the shoulder is in horizontal adduction and flexion, the acromioclavicular joint is subject to direct loading. Also, impact forces during the tackle that are higher than 5 kN would exceed the injury threshold suggested for the shoulder and needs to be considered in addition to the direction, height and speed of the tackle when evaluating the risk factors for acromioclavicular joint injuries (Seminati, Cazzola, Preatoni et al. 2017). Previous research has been inconclusive with regards to the use of shoulder padding for preventing shoulder injuries but this mechanism is in theory one that could be attenuated by the use of padding and warrants further research (Headey, Brooks and Kemp 2007, Usman, McIntosh and Frechede 2011, Usman, McIntosh, Quarrie et al. 2015).

Shoulder sprains and dislocation had a relatively high rate of recurrence at 36%. The higher rate of new dislocations than recurrent is likely attributable to the high risk activities (typically contact situations involving the tackle) performed by players during matches (Brooks and Kemp 2008). Headey and co-workers were in agreement with the present data that the severity of reported recurrences of dislocation/ instability was higher than new injuries (Headey, Brooks and Kemp 2007). It is worth noting the limitation of the analysis method for reporting recurrences here, which does not provide a direct comparison between the individual recurrent injuries and their own index injury, merely a comparison of mean severity values of each category. Management and rehabilitation may also need to be enhanced by considering positional specific return to play criteria to attempt to reduce the proportion of recurrence (Beardmore, Handcock and Rehrer 2005, Sundaram, Bokor and Davidson 2011).

There was no significant difference in incidence of shoulder injuries between forwards and backs. Back row forwards sustained significantly more injuries than second row forwards. Research has shown that back row flankers were among the three most common positions to sustain shoulder instability that required reconstructive surgery (Sundaram, Bokor and Davidson 2011). Position specific physical conditioning for the shoulder and a graduated return to sport is warranted to reduce the risk and severity of shoulder injury (Brooks and Kemp 2011, van Rooyen 2012).

Unlike some other previous studies, we found no difference in incidence between match quarters (Fuller, Brooks, Cancea et al. 2007, Cunniffe, Proctor, Baker et al. 2009). We have shown lower severity in quarter 1 which may be due to players not being fatigued and therefore fatigue not being a factor.

In the current study a limitation was a lack of reporting on training injuries which possess an injury burden in themselves and may be a risk factor for match injury. In this context, injuries that happen during training may result in the gradual onset of deficits in players' functional movement patterns thereby reducing players' ability to perform in an efficient way to withstand the forces of impact during the game and so contribute to injuries occurring. It is possible that specific assessment of dysfunctional movement around the shoulder with subsequent correction may be of benefit.

This study presents the first focussed analysis of the nature of shoulder injuries in English community-level rugby union match play. Tackling is the main event associated with injury, while injuries to the acromioclavicular joint had the highest incidence. All parties involved in the game need to focus on coach and player education around tackle technique and specific physical conditioning, and research should continue to determine the factors that contribute to shoulder injuries so as to direct prevention strategies. Before determining these contributing risk factors, it is necessary to evaluate the reliability of the tests used in identifying shoulder injury risk factors.

Chapter Four

The reliability of the scapular posture and scapular dyskinesis tests in rugby union players.

Introduction

Frequent impact forces to the shoulder can lead to repetitive microtrauma (Safran 2004, Usman, McIntosh and Frechede 2011) which has been shown to subsequently create motor control and kinematic alterations that may cause or contribute to shoulder conditions such as sub-acromial impingement syndrome and shoulder instability (Ludewig and Reynolds 2009, Kawasaki, Maki, Shimizu et al. 2014, Larsen, Juul-Kristensen, Lund et al. 2014). These alterations appear to primarily affect the orientation and motion of the scapula during both normal shoulder function and during sport (Kibler, Ludewig, McClure et al. 2013). It is essential that clinicians are able to reliably assess scapular orientation and motion in a valid way in players at risk of developing shoulder conditions and in those with shoulder pain (Wright, Wassinger, Frank et al. 2013, Clarsen, Bahr, Andersson et al. 2014, Struyf, Nijs, Mottram et al. 2014).

During normal shoulder motion it is imperative that the scapula maintains the humeral head centralised on the glenoid, which is reliant on the synchronised and coordinated activation of scapulohumeral muscles in force-coupled patterns (Kibler 1998). For example, a proximal to distal coupling pattern of activation involving the scapular stabilisers before the arm positioners and rotator cuff occurs during a tennis serve, baseball pitching (Kibler, Chandler, Shapiro et al. 2007) and tackling in rugby (Herrington and Horsley 2009). Repeated tackle collisions have the potential to alter this dynamic control, which could reduce the ability of the shoulder girdle to resist high deceleration forces at the point of impact, resulting in injury (Herrington, Horsley, Whitaker et al. 2008, Morgan and Herrington 2014, Faria, Campos and Jorge 2017). This highlights the importance of routinely evaluating scapular dysfunction in the clinical assessment and rehabilitation of sporting populations with shoulder pain (Kibler, Ludewig, McClure et al. 2013).

Scapular orientation

Current literature describes the orientation (anterior tilting and downward rotation) and altered dynamic control of the scapula being associated with shoulder pain and the risk of injury (Kawasaki, Yamakawa, Kaketa et al. 2012). Alterations to scapular position may be caused by multiple factors, with the large majority related to muscular imbalances and impaired motor control (Cools, Struyf, De Mey et al. 2014). Observation of resting scapular position can be performed by dividing the position into multiple planes of reference, which is consistent with contemporary kinematic analysis (Struyf, Nijs, Mottram et al. 2014, O'Leary, Christensen, Verouhis et al. 2015). Separating the evaluation of the scapula into planes of motion has shown moderate inter-therapist reliability (kappa 0.42) when examining 15 participants with neck pain (O'Leary, Christensen, Verouhis et al. 2015). In another study the test–retest reliability of this scapular posture rating assessment was investigated by five qualified physical therapists observing 50 healthy participants (McPhail, Dalland, Naess et al. 2012). Test-retest agreement ranged from 59% to 87% while the kappa values were inconsistent and showed fair to moderate reliability. Visually rating the scapula requires the judgement of the clinician to visualise the position of a flat bone that is suspended on the posterior thoracic cage, overlaid by a multi-layer envelope of soft tissue structures (Kibler, Ludewig, McClure et al. 2013). Therefore, the need for subjective judgement may limit the novice therapist's ability to identify impairments (Aasa, Lundstrom, Papacosta et al. 2014). As such, O'Leary and colleagues called for future research to investigate whether differences in experience levels impacts inter-therapist reliability (O'Leary, Christensen, Verouhis et al. 2015).

Clavicular tilt angle

The clavicle is part of the shoulder girdle and the clavicle tilt angle (CTA; angle between the horizontal and long axis of the clavicle) can influence scapular position and be useful in determining scapular orientation (Ha, Kwon, Weon et al. 2013). Multiple impact forces to the clavicle in the rugby tackle (Pain, Tsui and Cove 2008, Usman, McIntosh and Frechede 2011, Faria, Campos and Jorge 2017) may lead to alterations to the CTA, resulting in abnormal scapular orientation. Clinical evaluation should therefore not overlook the importance of evaluating clavicle position.

The reliability of goniometric and photographic measurements of the CTA in static, healthy participants (n=18) has been shown to be excellent when assessed by two experienced therapists, with goniometric inter-rater reliability ICC = 0.85 – 0.87 and intra- therapist reliability ICC = 0.80 (Ha, Kwon, Weon et al. 2013). Inter-rater reliability of the photographic measurements were ICC = 0.89 – 0.95, while intra- therapist reliability ICC = 0.84 (Ha, Kwon, Weon et al. 2013). Furthermore, the validity of the goniometric and photographic measurements of the CTA was compared to radiographic findings and shown to be highly correlated (r = 0.83 and 0.78, respectively) (Ha, Kwon, Weon et al. 2013). Goniometric measurement of the CTA is accessible in clinical practice, though there are no published normative data which makes clinical interpretation of the angular measurement unclear.

Scapular Dyskinesis

Scapula malposition and movement impairment is termed scapular dyskinesis (SD) (Kibler, Uhl, Maddux et al. 2002, Kibler, Ludewig, McClure et al. 2009), which can be assessed clinically using visual observation (Kibler, Uhl, Maddux et al. 2002, McClure, Tate, Kareha et al. 2009) including palpation (Baertschi, Swanenburg, Brunner et al. 2013, Huang, Huang, Wang et al. 2015), symptom alteration tests (Kibler, Ludewig, McClure et al. 2013) and with more advanced laboratory methods involving 3-dimensional motion analysis (Ludewig and Cook 2000). The Scapular Dyskinesis Test (SDT) is a visual observation protocol that is widely adopted in clinical practice as it is readily available, time efficient and does not require any sophisticated equipment (Christiansen, Moller, Vestergaard et al. 2017). The SDT has shown moderate inter–rater reliability (weighted kappa 0.54) (McClure, Tate, Kareha et al. 2009) and concurrent validity has been demonstrated with 3-dimensional motion analysis (Tate, McClure, Kareha et al. 2009); however, these studies suffer from diverse test procedures and poor methodological quality (D'Hondt, Kiers, Pool et al. 2017). The primary issue for the modest reliability findings is a lack of consensus of what constitutes a 'normal' scapular position, which inevitably influences judgement regarding abnormality (O'Leary, Christensen, Verouhis et al. 2015). In addition, a recent review demonstrated a lack of consistency in methods of assessing scapular orientation and varied study quality ranging from 14 out of 26 (54%) to 19 out of 26 (73%) when using the Downs and Black quality assessment tool (Ratcliffe, Pickering, McLean et al. 2014). There is also a paucity of rugby-specific evidence which offers clinicians limited confidence to use these tests when working in this field-based sporting environment.

The reliability of clinical tests requires sufficient time to develop consistent performance and standardised definitions, it can be argued should be gained with experience. This may lead to inconsistent and unreliable ratings by novice rater. Therefore, the purpose of this study was to assess the inter- and intra-rater reliability between expert and novice therapists when assessing static scapular posture, clavicular tilt angle, and scapular dyskinesis in rugby union players within a realistic team setting.

Methods

Participants and setting

An inter- and intra-rater reliability study was conducted with four novice rater and one experienced therapist who independently rated the static scapular posture, clavicular tilt angle and scapular dyskinesis of rugby union players. The novices were undergraduate students in the final year of a 3-year honours degree in sport rehabilitation, while the experienced therapist was a chartered physiotherapist with 15 years of experience in the assessment and management of musculoskeletal conditions. All novice raters underwent a test familiarisation session with the experienced therapist prior to the test days.

Participant characteristics

Participants were recruited during the competitive season (September to December 2015) from a squad of 60 players in a university men's rugby union team (Figure 5). Participant mean age was 21 years (standard deviation (SD)+/- 1.1 years) and mean weight was 91 kg (SD +/- 7.9 kg). Players reported no current shoulder pain or shoulder injury in the previous six months and had full range of movement in shoulder abduction as screened by the experienced study therapist using the painful arc test (Kessel and Watson 1977). Players had not trained prior to testing. These criteria ensured that pain was not a confounding factor to the position and motion of the shoulder. All participants volunteered and provided written informed consent. The University of the West of England, Bristol Faculty Research Ethics Committee granted ethical approval for this study. The Guidelines for Reporting Reliability and Agreement Studies (GRRAS) has been followed in reporting this study (Kottner, Audige, Brorson et al. 2011).

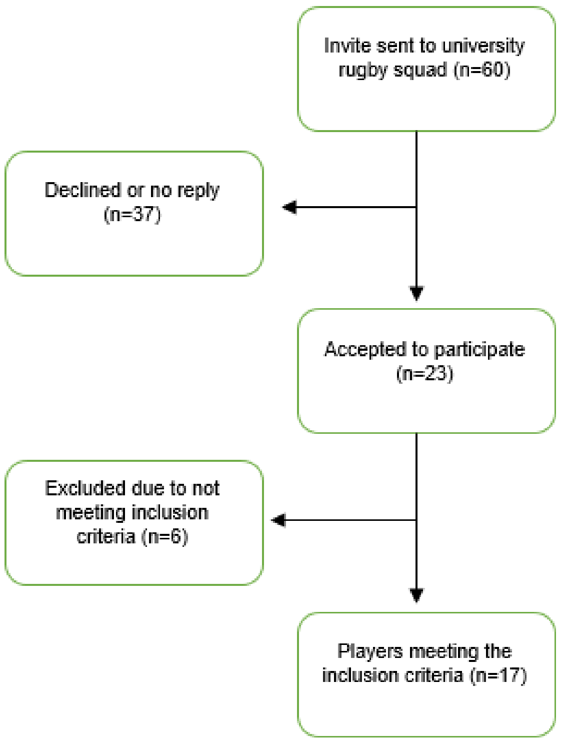

Figure 5: Flowchart of player participation through study (n= number of players)

Procedure

Participants attended three testing sessions (session 1: n=17, session 2: n=12 and session 3 n=16), each one week apart. The inter-rater analysis included all participants from each session, while the intra-rater analysis included only the 12 participants who attended all three testing sessions. Each participant was randomly allocated to a rater upon arrival for testing in a sport changing room. Data collection was conducted immediately before a training session, which meant that raters had a short duration to perform the assessments. Each player's profile was completed using a standardised baseline questionnaire that included a randomly generated participant number, date of birth and weight. The rater observed the participant's scapular posture posteriorly by allocating one of three ordinal ratings in five planes of movement (Table 8 and Figure *6*). The rater then observed the participant from the front so that they could determine the level of the clavicle relative to the horizontal. This measurement was made by the rater observing whether the mid-point of the acromioclavicular joint (distal end) of the clavicle was lower than, level with, or higher than the mid-point of the sternoclavicular joint (proximal end) (Table 9). All ratings were made with the participants standing with their arms resting at their side (0º abduction). The shoulder assessments were carried out unilaterally for both arms, with the participants barefoot, topless and wearing rugby shorts. Raters were permitted to use small circular stickers to place on bony landmarks to assist in determining the orientation of the scapula.

To ensure that all raters observed the same repetitions of the dynamic movement during the scapular dyskinesis test, this test was video recorded by a novice therapist at all 3 testing sessions and the video was viewed and independently evaluated by all raters the next day. This dynamic test was done according to the procedure described by McClures et al. (2009) using a video camera capturing a posterior view (McClure, Tate, Kareha et al. 2009). The rating of the quality of movement for this test was scored independently for each arm and independently rated by each therapists using the operational definition for the scapular dyskinesis test described in Table 10 (McClure, Tate, Kareha et al. 2009).

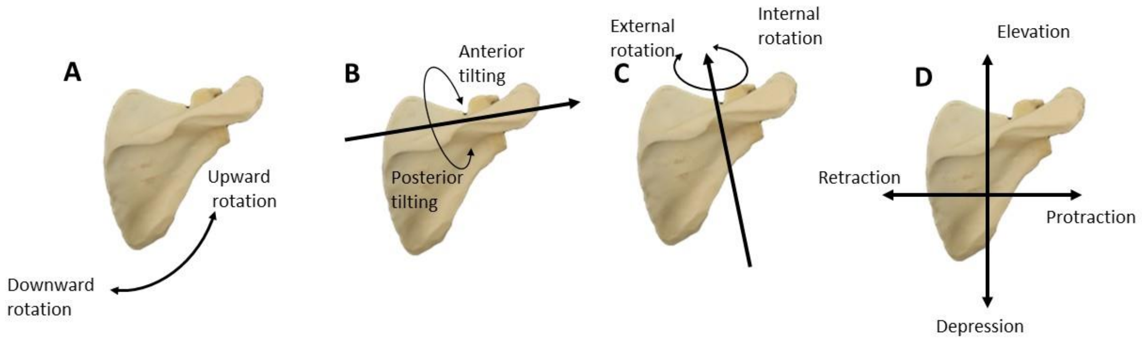

Figure 6: Scapular posture in five planes of movement including the scapular plane (A), sagittal plane (B), transverse plane (C), vertical and horizontal plane (D).

Rating	Criteria
Scapula plane	
Upwardly rotated	The inferior angle of the scapula was furthest away from the midline than the superior angle of the scapula
Neutral	The inferior angle and superior angle of the scapula was equidistant from the midline
Downwardly rotated	The superior angle of the scapula was furthest away from midline than the inferior angle of the scapula
Sagittal plane	
Anteriorly tilted	The scapula has a prominently raised inferior angle relative to the thorax and the superior angle.
Neutral	The scapula is positioned flat on the thorax with no prominent borders or angles.
Posteriorly tilted	The scapula has a prominently raised superior angle relative to the thorax.
Transverse plane	
Internally rotated	The scapula has a prominently raised medial border relative to the thorax.
Neutral	The scapula is rotated forward with no prominence of the medial border of the scapula relative to the thorax.
Externally rotated	The scapula exhibiting minimal or no forward rotation in the transverse plane.
Vertical plane	
Elevated	The superior and inferior angle of the scapula superior to T3-4 and T7-9 respectively.
Neutral	The superior and inferior angle of the scapula level with T3-4 and T7-9 respectively.
Depressed	The superior and inferior angle of the scapula inferior to the T3-4 and T7-9 respectively.
Horizontal plane	
Protracted	The medial border of the scapula rests more than 2 inches from the midline
Neutral	The medial border of the scapula rests approximately 2 inches from the midline
Retracted	The medial border of the scapula rests less than 2 inches from the midline

Table 8: Criteria for rating scapular posture

Clavicle tilt angle	Criteria
Upward inclined	The distal end of the clavicle is superior to the proximal end in the horizontal plane.
Level	The distal end of the clavicle is horizontally aligned with the proximal end.
Downwardly inclined	The distal end of the clavicle is inferior to the proximal end in the horizontal plane.

Table 9: Criteria for rating the clavicle title angle

<table>
<tr><td colspan="2">Normal scapulohumeral rhythm: Stable scapula with minimal motion during the initial 30º to 60º of shoulder abduction, the scapula then moves smoothly and continuously rotating upward during abduction and smoothly and continuously rotates downward during adduction of the shoulder. No winging is present.</td></tr>
<tr><td colspan="2">Scapular dyskinesis: Either one or both of the following abnormalities may be present.</td></tr>
<tr><td colspan="2">Dysrhythmia: Scapular motion occurs prematurely or excessive elevation or protraction, during abduction or adduction of the shoulder the motion is not smooth or stuttering, or rapid downward rotation during adduction.</td></tr>
<tr><td colspan="2">Winging: The inferior angle and /or medial border of the scapular posteriorly displaced away from the thorax.</td></tr>
<tr><td colspan="2">Rating scale (used for flexion and abduction)</td></tr>
<tr><td>Score</td><td>Description</td></tr>
<tr><td>1</td><td>Normal motion is depicted by no evidence of abnormality</td></tr>
<tr><td>2</td><td>Subtle abnormality is mild or questionable, not consistently present</td></tr>
<tr><td>3</td><td>Obvious dysrhythmia or winging is striking, clearly apparent, evident on at least 3/5 repetitions</td></tr>
<tr><td colspan="2">Rating scale (used for combined flexion and abduction test movements)</td></tr>
<tr><td>Score</td><td>Description</td></tr>
<tr><td>1</td><td>Normal is both tests rated as normal or 1 motion is rated as normal and the other is subtle abnormality</td></tr>
<tr><td>2</td><td>Subtle abnormality is both flexion and abduction is rated as subtle abnormality</td></tr>
<tr><td>3</td><td>Obvious abnormality in either flexion or abduction is rated as obvious abnormality</td></tr>
</table>

Table 10: Scapular Dyskinesis Test: description of operational definitions and rating scale

(Permission granted by Journal of Orthopaedic & Sports Physical Therapy, from McClure P, Tate AR, Kareha S, Irwin D, Zlupko E. A Clinical Method for Identifying Scapular Dyskinesis, Part 1: Reliability. Journal of Athletic Training. 2009;44(2):160-164).

Analysis

Inter-therapist agreement was evaluated with weighted kappa (using the SPSS Extension command) (Cohen 1960) as the outcome is ordinal data and interpreted using the definition in Table 11 (Landis and Koch 1977). Each novice raters' (rater 1 to 4) observation was compared to that of the experienced therapist.

Kappa Statistic	Strength of Agreement
<0.00	Poor
0.00-0.20	Slight
0.21-0.40	Fair
0.41-0.60	Moderate
0.61-0.80	Substantial
0.81-1.00	Almost Perfect

Table 11: Agreement measures for categorical data.

(Note: Permission has been granted to use this table by the original author (Landis and Koch 1977)).

Intra-rater agreement was evaluated using unweighted Cohen's kappa analysis. Each shoulder was treated as independent with pooled data from the left and right ratings analysed for each plane and condition (O'Leary, Christensen, Verouhis et al. 2015). Using the kappa coefficient when investigating nominal data can be influenced by prevalence of responses in each category and bias within the data of paradoxical observations of high exact agreement and low kappa coefficients (O'Leary, Lund, Ytre-Hauge et al. 2014). Attempts to correct for this by adjusting the kappa coefficient have been suggested, but are criticised as representing an artificial coefficient when the dataset reflect real life occurrences. In light of these issues, this study's approach was to calculate the kappa coefficient and the exact agreement (the proportion of cases where both raters agree compared to all cases considered). All analyses were conducted using IBM SPSS Statistics for Windows, Version 24.0 (Corp. 2015).

Results

Inter-rater reliability

The reliability for the scapular posture test ranged from -0.04 to 0.46 (Table 12), which is poor to moderate agreement. Agreement was higher between all rater in the sagittal plane (fair to moderate) than any other plane of movement. Percentage agreement ranged from 18% to 97%.

Plane of movement	Rater one versus five	Rater two versus five	Rater three versus five	Rater four versus five	Mean
			Weighted Kappa (Percentage Agreement)		
Scapula	0.07 (34%)	0.04 (24%)	0.08 (30%)	-0.04 (18%)	0.04 27%
Sagittal	0.22 (62%)	0.44 (78%)	0.21 (68%)	0.46 (73%)	0.33 53%
Transverse	0.00 (52%)	0.00 (50%)	0.00 (71%)	0.00 (52%)	0.00 56%
Horizontal	0.00 (93%)	0.00 (97%)	0.00 (92%)	0.00 (91%)	0.00 93%
Vertical	-0.02 (93%)	0.00 (97%)	0.00 (97%)	-0.02 (88%)	-0.01 94%

Table 12: Inter-rater agreement for scapular posture

(weighted kappa values and percentage agreement) and mean agreement (A 0.00 score was calculated for ratings where the values were a constant and indicated perfect agreement).

For clavicle tilt angle (Table 13), inter-rater reliability ranged from 0.04 to 0.32, which is slight to fair agreement. Percentage agreement ranged from 50% to 64%.

Rater	Rater 5						
	Weighted Kappa	Standard Error	z	value	Lower 95% CI	Upper 95% CI	Percentage agreement
1	0.19	0.10	1.89	0.06	-0.00	0.38	58%
2	0.27	0.10	2.55	0.01	0.07	0.47	62%
3	0.04	0.06	0.67	0.50	-0.08	0.16	50%
4	0.32	0.10	3.10	0.00	0.13	0.51	64%
Mean	0.21						59%

Table 13: Inter-rater agreement for observation of clavicle tilt angle

(Weighted Kappa values and percentage agreement)

For SDT, inter-rater reliability for abduction ranged from 0.07 to 0.30, which was slight to fair agreement (Table 14). Flexion ranged from -0.02 to 0.18 (slight to fair agreement) and the combined movement ranged from 0.06 to 0.24 (slight to fair agreement). The percentage agreement ranged from 32% to 60%.

Rater	Rater 5					
	Abduction		Flexion		Combined	
	Weighted Kappa (percentage agreement)	Standard Error	Weighted Kappa (percentage agreement)	Standard Error	Weighted Kappa (percentage agreement)	Standard Error
1	0.07 (57%)	0.09	0.16 (47%)	0.08	0.23 (47%)	0.07
2	0.08 (58%)	0.08	-0.02 (38%)	0.07	0.11 (43%)	0.05
3	0.30 (60%)	0.09	0.18 (48%)	0.08	0.24 (43%)	0.07
4	0.24 (43%)	0.09	0.14 (43%)	0.07	0.06 (32%)	0.06
Mean Kappa	0.17		0.11		0.16	
Percentage Agreement	60%		44%		41%	

Table 14: Inter-rater agreement for scapular dyskinesia (Weighted Kappa and percentage agreement)

Intra-rater reliability

For scapular posture, intra-therapist agreement ranged from 0.00 to 1.00 (Table 15).

Plane of movement	Rater one			Rater two			Rater three			Rater four			Rater 5			Mean
	Day 1 versus 2	Day 2 versus 3	Day 1 versus 3	Day 1 versus 2	Day 2 versus 3	Day 1 versus 3	Day 1 versus 2	Day 2 versus 3	Day 1 versus 3	Day 1 versus 2	Day 2 versus 3	Day 1 versus 3	Day 1 versus 2	Day 2 versus 3	Day 1 versus 3	Kappa Percentage Agreement
Scapula	0.05	0.01	0.05	0.00	0.00	0.00	0.23	0.06	0.10	0.66	0.30	0.25	0.16	0.07	0.75	0.22
	38%	67%	38%	79%	100%	79%	79%	83%	71%	83%	58%	58%	63%	58%	92%	70%
Sagittal	0.41	0.05	0.39	0.11	0.50	0.25	0.56	0.46	0.46	0.25	0.58	0.67	0.48	0.44	0.32	0.43
	75%	63%	75%	67%	83%	75%	83%	75%	75%	63%	79%	83%	75%	75%	67%	74%
Transverse	0.14	0.42	0.24	0.52	0.78	0.33	0.00	0.09	0.00	0.28	0.43	0.60	0.27	0.25	0.10	0.34
	63%	33%	46%	79%	92%	71%	92%	83%	92%	63%	71%	83%	58%	63%	42%	69%
Horizontal	0.11	0.65	0.07	0.00	0.00	0.00	0.48	0.48	1.00	0.46	0.06	0.65	0.00	0.00	0.00	0.44
	79%	96%	83%	100%	100%	100%	92%	92%	100%	92%	88%	96%	100%	100%	100%	95%
Vertical	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.46	0.46	0.14	0.00	0.00	0.48	0.44	0.32	0.24
	88%	100%	88%	100%	100%	100%	100%	100%	100%	75%	88%	79%	96%	100%	96%	94%

Table 15: Intra-rater agreement of scapular posture (Cohen's Kappa values and percentage agreement) and mean agreement.

(A 0.00 score was calculated for ratings where the values were a constant and indicated perfect agreement).

Agreement of the clavicle tilt angle ranged from 0.02 to 0.65, which is slight to substantial agreement (Table 16).

Rater	Day 1 versus 2	Day 2 versus 3	Day 1 versus 3
1	0.52	0.02	0.05
	83%	54%	54%
2	0.57	0.50	0.42
	79%	75%	71%
3	0.03	0.65	0.21
	88%	96%	92%
4	0.48	0.49	0.39
	79%	75%	71%
5	0.58	0.52	0.48
	79%	79%	75%
Mean Kappa Percentage Agreement	0.39 77%		

Table 16: Intra-rater agreement for observation of clavicle tilt angle (Cohen's Kappa values and percentage agreement)

For SDT, the intra-rater reliability for abduction ranged from -0.17 – 0.55 which was slight to moderate agreement. Flexion ranged from 0.03 – 0.33 (slight to fair agreement), and the combined movement ranged from -0.17 – 0.51 (poor to moderate agreement) (Table 17). The highest agreement was achieved by rater 1 ranging from 0.17 to 0.55 (slight to moderate reliability).

Scapular Dyskinesis	Rater one			Rater two			Rater three			Rater four			Rater 5			Mean
	Day 1 versus 2	Day 2 versus 3	Day 1 versus 3	Day 1 versus 2	Day 2 versus 3	Day 1 versus 3	Day 1 versus 2	Day 2 versus 3	Day 1 versus 3	Day 1 versus 2	Day 2 versus 3	Day 1 versus 3	Day 1 versus 2	Day 2 versus 3	Day 1 versus 3	Kappa Percentage Agreement
Abduction	0.55	0.30	0.18	0.26	0.47	0.19	0.02	0.09	0.06	0.26	0.03	0.29	0.20	0.13	0.01	0.20
	79%	67%	63%	71%	79%	67%	50%	50%	50%	71%	63%	71%	71%	54%	46%	63%
Flexion	0.28	0.26	0.17	0.03	0.15	0.13	0.17	0.23	0.23	0.08	0.33	0.05	0.07	0.17	0.03	0.16
	67%	54%	29%	58%	54%	29%	63%	58%	21%	46%	67%	46%	38%	42%	29%	47%
Combined	0.51	0.23	0.10	0.23	0.17	0.17	0.00	0.17	-0.02	-0.17	-0.08	0.03	0.07	0.02	0.31	0.12
	75%	50%	42%	67%	58%	58%	42%	50%	25%	42%	42%	42%	42%	17%	58%	47%

Table 17: Intra-rater reliability for scapular dyskinesis (Cohen's Kappa values and percentage agreement) and mean agreement

Discussion

This was the first field-based study to evaluate inter- and intra-rater reliability between novice and experienced rater for the visual ratings of static scapular posture, clavicular tilt angle and scapular dyskinesis in asymptomatic rugby union players' shoulders. Rater ratings showed a wide range of variability for all tests, yielding generally low reliability. Visual observation of scapular posture varied up to 0.33 (weighted kappa) between different experience levels of rater in this study. The visual rating of the orientation of the scapula using the five planes of motion (McPhail, Dalland, Naess et al. 2012) as a reference did not have any better utility and did not improve reliability for the experienced or less experienced rater in this study.

The inter-therapist agreement was lower (mean kappa 0.16) than reported values in a study that used therapists with different experience levels for the Scapular Dyskinesia Test (0.54) (McClure, Tate, Kareha et al. 2009). In our study, therapists were provided with test instructions and normal and abnormal motion was described to them; however, they did not train using actual examples of people with abnormal motion, which is inherently limiting (McClure, Tate, Kareha et al. 2009). The examples of abnormal motion used in training seem to be an important component as does the length of training provided for raters. This was apparent in a recent study on 162 elite adolescent handball players (Moller, Attermann, Myklebust et al. 2018) which used two final year physiotherapy students to evaluate the inter-therapist reliability for scapular control. The raters in their study underwent two hours of training followed by two pilot testing sessions prior to data collection that involved 20 physiotherapy students in the first pilot and 45 youth handball players in the second. These raters received significantly more training than the raters in our study, which may have been a factor in their greater levels of agreement (kappa range 0.67 to 0.84). Routine practice of this clinical test is therefore recommended for clinicians to reduce measurement errors.

Agreement for the Scapular Dyskinesia Test observed in this study was also lower than that found by novice rater (kappa=0.59) in a study that was published after the present study was conducted (Christiansen, Moller, Vestergaard et al. 2017). That study was conducted on 40 patients with subacromial impingement and only used two novice rater, concluding that there were wide confidence intervals with fair limits of agreement (0.38) when using the Landis and Koch (Landis and Koch 1977) threshold and relatively large differences between the two novice rater for both inter- and intra-rater reliability. A large range in the upper and lower limits for results in that study mirrors our findings, indicating that the Scapular Dyskinesis Test is classified and interpreted differently by rater with different experience levels. Using the operational definition in the SDT (described in Table 10) requires the clinician to detect subtle variations of a number of types of dyskinesis that may not be easy to consider simultaneously. The determinants for the thresholds of dysrhythmia are not clearly defined and equally may not be obviously apparent (Forthomme, Crielaard and Croisier 2008, Lange, Matthijs, Jain et al. 2017). For example, determining when movement is premature or how much elevation or protraction of the scapula is considered excessive requires clinical judgement. Unless there is an obvious abnormality present, the likelihood of detecting a subtle abnormality may be low between rater or between time points. The study on elite adolescent handball players (Moller, Attermann, Myklebust et al. 2018) used a version of the SDT test that was modified from that described by McClure et al. (2009). They modified the three-option categorization (normal, subtle or obvious) and applied a dichotomized (eg: absent or present) category instead using normal (normal + subtle dyskinesis) or obvious categories and achieved a greater k value (0.67 to 0.84) than in our study. This has also been argued elsewhere to be a more suitable method to use for research and clinical use (Struyf, Nijs, Mottram et al. 2014).

Simultaneously comprehending multiple dysfunctional movement patterns in numerous planes of movement during an observational assessment is difficult (Kibler, Uhl, Maddux et al. 2002). In a study involving a combination of participants with and without shoulder pain (n=26), scapular dyskinesis was divided into four subcategories from type I to IV (Kibler, Uhl, Maddux et al. 2002). Type I included the presence of inferior angle, type II had medial border prominence while type III involved superior border prominence and type IV being symmetric scapulohumeral motion. The researchers recognised that a limitation of their system was that combined patterns of dyskinesis exist due to patients' adaptations, which adds to the complexity of the observation of dyskinesis. Though the rating system is not comparable to that used in the present study, it is noteworthy that the authors concluded that completing fewer than 10 arm elevations/ lowering cycles may be insufficient to elicit a predominant pattern. The present study used five repetitions while holding weights as outlined in the methods from McClure et al. (2009), which may have decreased the reliability of the results.

The importance of being able to reproduce the conditions that impose an increased demand to the shoulder and result in dysfunctional movement patterns has been highlighted. Using heavier weights during SDT has been implicated in greater reliability of clinical assessments (Moller, Attermann, Myklebust et al. 2018). It is therefore plausible to recommend that the imposed stress needs to be sufficiently challenging to provoke a movement impairment while taking into consideration the individuals' level and sport demand. This may be achieved by using a heavier dumbbell weight (Moller, Attermann, Myklebust et al. 2018) or increasing the number of repetitions (Ben Kibler, Uhl, Maddux et al. 2002). For the SDT to impose a sufficient stress in rugby players' shoulders, the challenge may need to be even greater than the weights used in the present study.

Test-retest reliability performed one week apart showed similar fair to moderate reliability (mean range 0.22 – 0.44) as found by other investigators for scapular posture (McPhail, Dalland, Naess et al. 2012). High exact agreement was seen with scapular planes with results exceeding 69% agreement which was also similar to previous findings (McPhail, Dalland, Naess et al. 2012). A substantial proportion of ratings were different between assessment days, ranging from 0.00 – 1.00 and 33% - 100% for the kappa statistic and percentage agreement, respectively. This wide range of intra-therapist reliability coefficients highlights the subjective nature and limitations of this type of clinical evaluation. There are two possible reasons for this disagreement from one testing session to the next: it may be due to inconsistency in rater ratings, or an actual difference in scapular posture between sessions. Potential factors that might have contributed to the variations in the scapular position at subsequent testing sessions could occur from players participating in strength and conditioning (Haupt 2001) or tackling during rugby training and matches (Herrington, Horsley, Whitaker et al. 2008, Morgan and Herrington 2014, Faria, Campos and Jorge 2017). These tests were evaluated in a real-world sport physical therapy setting and did not permit analysis of the cause of the disagreement. Yet, due to inconsistent reliability scores for these tests from one day to the next, their practical use in this sporting environment is brought into question. Clinicians need a consistently higher strength of agreement than moderate to enable them to confidently choose a test that will be useful in their decision making with athletes.

Intra-rater reliability of the SDT in this study showed only slight agreement, irrespective of the experience level of the rater. These findings were lower than that found by other investigators sampling inexperienced rater, who found substantial to almost perfect agreement in a non-athletic population with shoulder impingement syndrome (Christiansen, Moller, Vestergaard et al. 2017). The reasons for these findings are not dissimilar to those discussed for the variability of the inter-rater agreement. For example, the variation in the classification and interpretation of the test, the potential factors that could have contributed to actual variation of the dynamic scapular motion and inconsistent rater's observation. In addition, dynamic observational evaluation of the moving scapula could have added a level of complexity, making it challenging for the rater to detect faulty movement. In light of these factors, the low level of reliability for the SDT in this study does not provide sufficient support for its use in field-based testing conditions, irrespective of the level of experience of the rater.

This study found paradoxical low kappa values but high exact agreement for inter-rater reliability, similar to other investigations (O'Leary, Lund, Ytre-Hauge et al. 2014, Moller, Attermann, Myklebust et al. 2018). This was particularly true for the agreement of the scapula in the horizontal (91% - 97%) and vertical plane (88% - 97%), compared to kappa values of 0.00 and -0.02 to 0.00, respectively. Similarly, these findings were evident in the test-retest results in the scapula, vertical and horizontal planes, with kappa values as low as 0.00 while the exact agreement was 100%. These exact agreement values in the horizontal plane are likely due to the position of the medial border of the scapula being more than 2 inches away from the midline and its prominence in the physique of rugby players. Similarly, the position of the scapula in the vertical plane is an indication that the players' scapulae sit in normal position in this plane (Cooperstein, Haneline and Young 2015). In a homogeneous sample in which there is little variability, interpreting the results from the kappa statistic may be misleading and a combination of both statistics should be considered.

The present study has some limitations. Firstly, from a squad of 60 players only 23 volunteered and 17 met the inclusion criteria for this study. This meant that the sample size was below the general recommendation for obtaining reasonable precision for estimates of reliability that requires at least 20 participants to be recruited to the study (Walter, Eliasziw and Donner 1998). This prevents us from drawing firm conclusions regarding the reliability of the shoulder physical examination used in this study. This study did, however, meet the requirement for reliability studies to conduct at least 3 trials, which is a strength (Hopkins 2000). Another strength of this study was the pragmatic data collection approach in a field-based setting that reflected the real-world application, thus enhancing the ecological validity of the findings. However, the testing condition-imposed time constraints and environmental distractions, which meant that raters were under pressure when processing their judgement. This was overseen by the lead researcher (VS), but he was also conducting physical assessments at the same time. It is conceivable that the testing conditions could have impacted on the accuracy of the outcomes, leading to non-differential misclassification bias that may have resulted in underestimation compared to other studies where testing was conducted in a controlled clinical setting (McClure, Tate, Kareha et al. 2009, O'Leary, Christensen, Verouhis et al. 2015, Christiansen, Moller, Vestergaard et al. 2017). However, research has suggested that when inexperienced raters are in doubt, they overestimate the presence of scapular dyskinesis (Christiansen, Moller, Vestergaard et al. 2017).

Moreover, raters were allowed to mark bony landmarks on the players' scapula and clavicle using small circular stickers, which may have assisted the judgement of scapular orientation compared to an unmarked judgement. The use of video recording for the SDT allows all rater to observe the same movement but it does not allow for viewing of multiple angles normally available in a clinical setting and is considered a limitation in describing a 3-dimensional motion using a 2-dimensional video. Due to the lack of kinematic scapula measurement in this study, it cannot be determined if the experienced rater's scores were a true reflection of the actual scapular position. Further difficulty in using visual rating of the position of the scapula is the limitation in determining what is "normal" scapular alignment (Nijs, Roussel, Struyf et al. 2007). It is beyond the scope of this study to comment further on the objective criteria for defining normal scapular position. Despite these limitations, this study evaluated the reliability of these tests while considering raters' experience for the first time in a rugby playing population, offering new knowledge to this field of research.

Conclusion

Visual inspection of the static scapular posture, clavicular tilt angle and the scapular dyskinesis by novice and expert rater had low reliability in this field-based study. These findings highlight the limitation of this type of clinical evaluation and warrants that clinicians are aware of their variability. Both tests require further research to determine their validity and clinical utility. Visual observation was not consistent in this study and therefore does not seem to be an informative measure to be used when making clinical decisions by the clinician conducting a shoulder physical examination with rugby union players. Given the low reliability and recognised challenges identified in this study to assess shoulder injury risk factors, injury prevention exercise interventions should be targeted to all players and not only those identified by screening tests.

Chapter Five

The process for developing a shoulder-specific injury prevention programme in community youth rugby union.

Background

Shoulder injuries are amongst the most common injuries sustained by youth rugby players, with an overall severity that results in the highest number of days away from match play, irrespective of the injury definition used (Haseler, Carmont and England 2010, Bleakley, Tully and O'Connor 2011, Palmer-Green, Stokes, Fuller et al. 2013, Sabesan, Steffes, Lombardo et al. 2016, Archbold, Rankin, Webb et al. 2017). It is also apparent that shoulder injuries are a common problem across other playing levels; they were reported as the third most common rugby injury seen in US emergency departments between 2004 - 2013 in a cohort that included youth, collegiate and recreational players (Sabesan, Steffes, Lombardo et al. 2016). Shoulder injuries have been a persistent problem for English and Irish schoolboy rugby union players having been reported amongst the highest injury incidence and resulting in the greatest number of days lost in studies conducted during 2006 – 2008 (986 days lost) (Palmer-Green, Stokes, Fuller et al. 2013), 2008 – 2009 (Haseler, Carmont and England 2010) and 2014 – 2015 (Archbold, Rankin, Webb et al. 2017). They have also been reported to account for 553 days absent per 1000 hour between 2012 – 2015 (Barden and Stokes 2018). Even data from a long-term prospective study of elite youth players in the Junior World Championships and Junior World Rugby Trophies (n=659) over 8 seasons between 2008 and 2016 identified the shoulder/ clavicle was the most common injury sub-location (18.3%) (Fuller, Taylor and Raftery 2018). This trend is also supported by an earlier systematic review that found upper limb injury resulted in greater time loss than other sites in adolescent rugby players (Bleakley, Tully and O'Connor 2011). The epidemiology of shoulder injuries provides clear evidence that these injuries in youth rugby warrant priority in relation to the implementation of evidence-based injury prevention strategies.

Some targeted countermeasures to rugby injuries include scrum law changes (Cazzola, Preatoni, Stokes et al. 2014), the removal of illegal tackles from the game (Murray, Murray and Robson 2014), educational injury prevention programmes (Quarrie, Gianotti, Hopkins et al. 2007, Gianotti, Quarrie and Hume 2009, Viljoen and Patricios 2012), scrum safety protocols (Poulos and Donaldson 2012), protective equipment (McIntosh and McCrory 2001, Pain, Tsui and Cove 2008, McIntosh, McCrory, Finch et al. 2009, Harris and Spears 2010, Usman, McIntosh and Frechede 2011) and injury prevention exercise programmes (Hislop, Stokes, Williams et al. 2017, Attwood, Roberts, Trewartha et al. 2018). However, a critical review of injury prevention in child and adolescent sport found that research has primarily focused on the prevention of injuries in elite adult athletes where established injury prevention practices was supported by medical staff (Emery 2005). Subsequent reviews have highlighted that this has led community youth sports to rely on the recommendations from elite adult studies for injury prevention practices (Schiff, Caine and O'Halloran 2009, Lauersen, Bertelsen and Andersen 2014, Emery, Roy, Whittaker et al. 2015). There is considerable differences in the biological and sociocultural factors that influence injury risk in sport between adults and children (Schwebel and Brezausek 2014) which compels researchers to design preventive interventions specifically for a target group.

When considering research in youth sport specifically, reviews have suggested that injury prevention exercise programmes (IPEP) are a promising strategy to reduce the risk of sport injury (Rossler, Donath, Verhagen et al. 2014, Emery, Roy, Whittaker et al. 2015, Faude, Rossler, Petushek et al. 2017, Steib, Rahlf, Pfeifer et al. 2017). A recent meta-analysis of randomised control trials (RCT) in youth sport showed that when implemented as preseason or warm up training strategies, multifaceted lower extremity neuromuscular training routines reduced knee injuries by 45-83% and significantly reduced ankle injuries by 44-86% across youth sports (Emery, Roy, Whittaker et al. 2015). In addition, the combined effects of neuromuscular training demonstrated a significant overall protective effect [incidence rate ratios (IRR)=0.64; 95%confidence interval (CI) 0.49 to 0.84] against lower extremity injuries in youth team sport (soccer, European handball, basketball) (Emery, Roy, Whittaker et al. 2015). Another recent systematic review and meta-analysis showed that the FIFA 11+ (a neuromuscular training programme, hereafter referred to as 11+) substantially reduced soccer injuries by 39% in recreational / sub-elite players compared with controls (Thorborg, Krommes, Esteve et al. 2017). This consistent evidence supports the effect of multifaceted neuromuscular training programmes in reducing the risk of lower extremity injuries in various age groups and across different ball sports; however, there has been minimal research regarding upper limb injury prevention, and little emphasis on the community youth rugby setting.

There are a number of preventive exercise programmes that have shown efficacy in reducing the risk of lower limb injury in sport. These include Prevent Injury and Enhance Performance Programme (PEP) (Mandelbaum, Silvers, Watanabe et al. 2005, Gilchrist, Mandelbaum, Melancon et al. 2008), FIFA Medical Assessment and Research Centre (F-MARC) 11+ (Soligard, Myklebust, Steffen et al. 2008, Grooms, Palmer, Onate et al. 2013), HarmoKnee (Kiani, Hellquist, Ahlqvist et al. 2010), Knee Injury Prevention Programme (LaBella, Huxford, Grissom et al. 2011), Anterior Knee Pain Preventive Training Programme (Coppack, Etherington and Wills 2011) and Activate Injury Prevention Exercise Programme (Hislop, Stokes, Williams et al. 2017, Attwood, Roberts, Trewartha et al. 2018). The common features that emerge in the majority of these preventive programmes include sport-specific running-based exercises, targeted resistance training, perturbation and plyometric exercises. It is apparent that multicomponent preventive programmes that compose of strength and proprioception with exercise progressions included, led to reduced overall injury risk which was shown in a meta-analysis (Lauersen, Bertelsen and Andersen 2014). These components are therefore considered important across injury prevention exercise programmes in sport.

It is evident that neuromuscular training programmes have preventative benefits for lower extremity injury but most of them lack a shoulder component. As there are no studies evaluating shoulder injury prevention in rugby union players, evidence from other sports must be considered in developing a preventative shoulder neuromuscular training intervention for rugby. In response to shoulder injuries sustained by goalkeepers in football and the lack of a specific programme in the literature to reduce these injuries, the FIFA 11+ shoulder (FIFA 11+S) programme was developed (Ejnisman, Barbosa, Andreoli et al. 2016). This study described the development of an adapted 11+ programme and consisted of three parts: general warm up (part 1), strength and balance exercises for the upper extremity (part 2), and core stability and muscle control exercises (part 3). The FIFA 11+S is coach-led, lasting up to 20 - 25 minutes and requires light resistance equipment. A prominent feature of the FIFA 11+S programme is the emphasis given to strengthening exercises of the shoulder rotator cuff muscles; however, this intervention has not been well investigated and its efficacy is largely unknown. In addition to following the structure of the 11+ programme, the development process of the FIFA 11+S involved selecting exercises based on studies demonstrating high electromyographic activity of the shoulder and scapular muscles. The choice of exercises was further supported by their role in contributing to optimal shoulder function. A technical group consisting of orthopaedic experts in shoulder injury, physiotherapists with experience of working in soccer, and specialists in sports rehabilitation contributed to the development of the programme. This expert involvement ensured that the intervention would be specific to the injury mechanism of interest, and combining research evidence with clinical expertise is necessary to maximise the likelihood that the intervention will work by having a grounding in epidemiologic and aetiological evidence (Donaldson, Lloyd, Gabbe et al. 2016). Though the efficacy of the 11+S has not been evaluated, its development process provides a practical and generalisable process that can be applied to developing a similar intervention in other sports.

The Oslo Sports Trauma Research Centre (OSTRC) Shoulder Injury Prevention Programme (Andersson, Bahr, Clarsen et al. 2017) is another shoulder focused injury prevention exercise programme which was tested in a randomised controlled trial of 660 elite handball players. This exercise programme was created based on several modifiable risk factors for shoulder injury identified from the literature (Byram, Bushnell, Dugger et al. 2010, Moller, Attermann, Myklebust et al. 2012, Clarsen, Bahr, Andersson et al. 2014, Shanley, Kissenberth, Thigpen et al. 2015) and consisted of exercises aiming to increase glenohumeral internal range of motion, external rotation strength and scapular muscle strength. Exercise to improve the kinetic chain and thoracic mobility were also included. The 10-minute intervention was delivered by coaches and team captains on average 1.6 times per week during a regular season. Findings suggested that the risk of reporting shoulder problems (using the Oslo Sports Trauma Research Centre Overuse Injury Questionnaire (Clarsen, Myklebust and Bahr 2013)) during the competitive season was 28% lower in the intervention group (Odds Ratio (OR) 0.72, 95% CI 0.52 to 0.98, p=0.038) and there was a 22% lower risk of substantial shoulder problems (shoulder problems leading to moderate or severe reductions in training volume or performance, or total inability to participate) (OR 0.78, 95% CI 0.53 to 1.16, p=0.23) compared to a usual practice control. It is notable that there are similarities between the components of the OSTRC shoulder prevention programme and those described in the 11+ and 11+S, such as progressive strengthening, plyometric and core stability exercises. The commonality between the characteristics of these preventative interventions suggest that this approach is transferable to the upper limb and across sports, though it is unclear if this will hold true in a contact sport like rugby where traumatic injuries result in the most days away from competition.

Reviewing the literature for efficacious injury prevention programmes is fundamental when developing new interventions, but this does not ensure that the intervention will be effective. Evidence-based preventative interventions informs what interventions might work in tightly controlled research settings, however are not well implemented in the real world setting due to the intervention not being directly relevant to the specific implementation context (Donaldson, Lloyd, Gabbe et al. 2016, Donaldson, Lloyd, Gabbe et al. 2017). Investing time in finding out what might impact on uptake and maintenance of the intervention needs to be a significant priority when developing injury prevention programmes (Finch, White, Twomey et al. 2011).

Successful interventions based on studies carried out in “ideal conditions” afford certain benefits that are not always available in other settings. Teams participating in these studies are often supported by project staff responsible for injury surveillance delivery of the programme, and resources such as equipment is made available to support the intervention. The trouble with this approach is outlined in a sport injury prevention framework [Translating Research into Injury Prevention Practice (TRIPP)] (Finch 2006) which identifies that not all settings will have these personnel and resources available to them in the real-world context. Stages five and six of the TRIPP model emphasise that it is important to understand the barriers and facilitators to adoption and sustainability of preventative measures. Issues such as the lack of a reliable injury surveillance system, insufficient personnel available to deliver the preventative programme and equipment requirements are some of the barriers that need addressing when implementing injury prevention in community youth rugby settings.

There are also numerous contextual factors that need to be considered when implementing a preventative strategy in youth sport. It must inherently involve coaches and parents who need to know what is expected of them and how to fulfil their responsibilities. Thus, coach and parent input is a necessary source of information about the feasibility and sustainability of interventions to improve player welfare (Verhagen and van Mechelen 2010). Additional valuable advice about what may work best, is most feasible, affordable and sustainable can be gained from researchers working in tandem with practitioners, policy makers and others in the target community (Hanson, Allegrante, Sleet et al. 2014). This consultation can yield a clearer understanding about the political, social and environmental factors that are specific to community youth rugby and could influence full scale implementation of a prevention strategy.

Another key aspect to developing a prevention approach is to underpin the process in evidence-based practice with practitioner expertise and end user values (Donaldson, Lloyd, Gabbe et al. 2016). Feedback from the consultation with stakeholders may reveal valuable information local to the environment and club setting which may influence the implementation of the intervention. A number of valuable considerations can be revealed from consulting the end user, such as; determine if the format of the intervention is being presented in a way that will be acceptable to the target audience and if any revisions are necessary to best facilitate its implementation. This is an opportunity to evaluate how compatible the intervention might be with existing community youth rugby training and if they agree to replacing their existing warm-up or preventative practice with the one being proposed. The compatibility of the intervention may further explore if the language being used in the delivery process of the intervention is presented and descried in such a way that it is clear and easy to understand for all levels of end users (i.e., coaches, fitness staff, players and parents). Additionally, the end users' feedback provides a rich source of information in determining the resources available to the community clubs in them delivering and supporting the implementation of the intervention. Identifying the specific needs of the community youth rugby clubs to implement the intervention is imperative so not to over burden them with additional workload that may not be feasible or sustainable for them to deliver. Consequently, involving the end users in the development process may be beneficial in obtaining their favourable view of the implementation and delivery of the proposed intervention. The end user may be the source of local environmental knowledge that may prove practically useful when the intervention is being delivered.

There is no “one size fits all” for injury prevention that can be applied to any context and it is important to outline the process carried out in developing successful interventions for other researchers to follow. The process of how the intervention was developed and implemented is an important research area that is largely unreported in the literature but is required to assist other researchers with this knowledge to translate sport injury research into preventative practice. Now this is acknowledged in the literature and provides a generalizable and step-by-step guide (Donaldson, Lloyd, Gabbe et al. 2016). Applying this approach in developing future injury prevention exercise programmes will allow for a comprehensive understanding about developing and implementing a shoulder injury prevention programme in community youth rugby players.

Considering the framework of the FIFA 11+, 11+S and the OSTRC neuromuscular training programmes, collectively with established shoulder injury risk factors in rugby, will inform the development of an evidence-based preventative intervention. Consultation that includes a technical group of practitioner-experts in rugby shoulder injuries and all stakeholders is required to ensure that the interventions are practical and relevant in their context (Finch, Donaldson, Gabbe et al. 2016). Therefore, the purpose of this study was to describe the process to develop an implementable shoulder-specific injury prevention exercise programme (IPEP) for community youth rugby players.

Methods

The development of the shoulder injury prevention exercise programme recognised the importance of combining the best available scientific evidence with practitioner expertise and consultation with stakeholders. Four steps underpinned this process.

Step One

The researcher conducted a literature search on the Pubmed and the Web of Science databases between May and July 2016 to identify the strength and quality of the published research evidence pertaining to the benefits of neuromuscular training with the potential to reduce common shoulder injury risk factors in rugby. Additionally, the development process involved selecting exercises based on studies that identified modifiable shoulder injury risk factors in rugby players. The aim of this was to increase the likelihood that the intervention would be efficacious by ensuring a firm basis in the epidemiology and aetiological evidence of shoulder injuries in rugby. An important consideration in the selection of exercises from the literature was that they did not require specialist equipment that may impose any additional financial cost that could deter clubs from using the intervention in the real world (Emery, Cassidy, Klassen et al. 2005, Emery and Meeuwisse 2010).

Step Two

Effective multiagency partnerships have the potential to influence the implementation and the sustainability of the intervention was also considered in this project. Various approaches can be taken to determine the opinions of experts on this part of the design process such as using a Delphi study however due to the level of commitment required from the panellists and high drop-out level, it was not pursued for this step of the study. Step two, was completed in July 2016 with feedback from consultation with stakeholders (players, coaches and parents) and used to inform the research team of the most suitable strategy for delivering the intervention to the participating community youth rugby union clubs. The focus of the consultation was to identify the potential barriers to the uptake of the intervention and the sustainability of the sport safety interventions in their community club. Due to logistical difficulties for all stakeholders to meet together for this process, the researcher decided to gather their feedback using a combination of approaches (face to face or using an online survey). Responses were also obtained from a meeting with a coach who was also a parent of a player at a local rugby club, the club chairman and another parent and player completed an online questionnaire using google forms (n=4). The stakeholders were asked to comment on their views about potential barriers to implementing the intervention and its sustainability. Feedback was obtained in person from a coach who was also a player’s parent (n=1), club chairman (n=1) in person and from a parent and player (n=2) using an online survey.

Step Three

Outcomes from step one of the process, together with the feedback from the second step, informed the first draft of the shoulder IPEP to be presented to an invited multidisciplinary technical project group for consultation. The scope of the consultation was to obtain feedback on the delivery, content and implementation of the intervention in community youth rugby clubs. The group included academic, sporting and clinical expertise, including researchers who previously investigated the efficacy and effectiveness of injury prevention programmes in other sports, and medical and strength and conditioning practitioners from adult and youth level rugby union. The medical practitioners also included two specialist upper limb physiotherapists who are internationally recognised for their roles in professional practice and as researchers. The medical practitioners in the group were identified by their involvement in rugby and their specialist interest in shoulder rehabilitation. In response to invitations sent by email, the technical project group met face-to-face in August 2016 (n=6) and those who could not make it in person provided feedback on the programme via email (n=1) or telephone communication (n=1). The following items were discussed during the meeting: content of the warm up routine, delivery of the warm up routine and identify any issues of bias in the delivery of the intervention and control programmes. The lead researcher introduced the aims of the preventative intervention and described its general format which then allowed the technical project group to comment on the aforementioned agenda items. The feedback from the technical project group was tape recorded and transcribed verbatim by the researcher (VS) using a thematic content analysis. The research team considered all responses and their inclusion in the development process was based on the practicality and feasibility of the suggestions.

Step Four

The IPEP was tested in an acceptability and feasibility pre-study trial with two university level rugby players who were not part of any of the participating teams or involved in the study. This aimed to determine whether the exercises could be completed successfully. Trailing the routine allowed an opportunity to determine if any changes needed to be made to the programme structure and content prior to being delivered to community youth teams. The researcher conducted a trial run of the whole programme by demonstrating the exercises with verbal instructions. The two participants then went through the programme and provided feedback on the technical aspects of coaching and instruction. The participants' feedback was obtained verbally in a conversation and recorded by the researcher.

Results

Step One

The researcher prioritised the following injury prevention exercise programme and evidence-based corrective exercise interventions used to address shoulder injury risk factors as priorities that needed targeting in a preventative intervention; dynamic shoulder mobility, thoracic spine mobility, scapular control, rotator cuff muscle strength, upper limb plyometrics and exercises that incorporate core stability and the kinetic chain. Table 18 below outlines the key research studies identified that support the inclusion of exercises in the intervention.

Shoulder exercise intervention and modifiable risk factors	Author	Study Design	Participants	Outcomes
Upper limb preventative studies	(Andersson, Bahr, Clarsen et al. 2017)	RCT	Elite handball players (n=660)	28% lower risk of reporting shoulder problem.
Thoracic posture	(Bolton, Moss, Sparks et al. 2013)	Descriptive	University and senior professional rugby players (aged 17 -31 years, n=95)	66% of players has forward head posture, 60% of players thoracic spine khyphosis.
Shoulder and scapula muscle strength	(Ogaki, Takemura, Iwai et al. 2014)	Prospective cohort	Collegiate rugby players (age 19.5+/-1.3 years, n=69)	1.0 point increase in IR/ER strength ratio associated with 1.39 fold increase risk of shoulder injury (95% CI, 1.08 - 1.77; p=0.00).
	(Ogaki, Takemura, Shimasaki et al. 2016)	Prospective cohort	Collegiate rugby players (age 20.1+/-0.8 years n=28)	Injured players significantly lower maximal shoulder press (p=0.01; effect size 1.00), isometric shoulder IR (p=0.03, effect size 0.65), ER (p=0.04, effect size 0.67) and abduction (p=0.01, effect size 1.00).
	(Kawasaki, Yamakawa, Kaketa et al. 2012)	Prospective cohort	Professional rugby players (age 24.6 +/- 3.3 years, n=120)	32% players had impaired scapula control which was significantly associated with high risk of shoulder injury (Odds

				Ratio=4.4, 95% CI=1.8 to 10.7, p=0.001).
	(Cools, Johansson, Borms et al. 2015)	Literature review	Overhead athletes	Shoulder injury risk factors: GHJ IR deficit, RC (ER) strength, scapula dyskinesis (position and strength).
Upper limb stability and the kinetic chain	(Maenhout, Van Praet, Pizzi et al. 2010)	Repeated measures	Physically active participants (age 22.88+/-2.43 years, n=32)	Selected kinetic chain exercises stimulates scapula muscles activity.
	(De Mey, Danneels, Cagnie et al. 2013)	Descriptive Study	Overhead athletes (age 20+/-3.5 years)	Kinetic chain exercises stimulated higher trapezius muscle activity.
	(Yamauchi, Hasegawa, Matsumura et al. 2015)	Cross sectional study	Healthy men (age 21.5+/- 1.5 years, n=13)	Shoulder exercises with trunk rotation are effective in favourable scapula muscle recruitment.

Upper limb plyometrics	(Swanik, Lephart, Swanik et al. 2002)	Pretest/ posttest	Female swimmers (age 20+/- 1.10 years, n=24)	Significant improvement in proprioception/ kinesthesia and muscle performance.
	(Carter, Kaminski, Douex et al. 2007)	Pretest/ posttest	Collegiate baseball players (age 19.7+/-1.3 years, n=24)	Plyometric trained group increased throwing velocity (F[1,22]=11.56, p<0.05) compared to strength trained group
	(Maenhout, Benzoor, Werin et al. 2016)	Pretest/ posttest	Health participants (age 23.33+/-1.69 years, n=32)	Selected muscle recruitment for clinical practice

Table 18: Research findings of preventive shoulder injury exercise interventions modifiable risk factors

Additionally, exercises were included in the programme from randomised controlled trials that investigated neuromuscular training programmes that demonstrated efficacy and were relevant to rugby injuries. The outcome of step one of the process led to the first draft of the warm up routine, which had three parts: general warm up which included running drills (part 1), thoracic and shoulder mobility, shoulder and core stability, strength exercises (shoulder, scapula and hamstring) and upper limb plyometrics with all exercises incorporating the kinetic chain where appropriate (part 2), and fast running and agility drills (part 3). Part two of the programme included three levels of exercises that progressed in difficulty at each level. The structure of the routine was broadly based on the “11+” warm up, while the focus of the exercises in part two of the warm up routine was based on the findings from the literature review. This draft was presented to the technical project group for discussion during the consultation.

Step Two

Feedback from the stakeholders in step two informed the research team that the best way to train coaches to deliver the exercises to the team was to carry out a workshop (e.g., ‘coach the coach’) at the beginning of the study. Coaches felt that they would be more confident in delivering the warm up routine to players during the season if they believed that the warm up routine worked. The coach was also considered the best delivery agent for the warm up. The feedback from the stakeholders identified that coaches and players would sustain the warm up routine if it worked and the players enjoyed it. There were no barriers identified by the stakeholders to using the warm up routine.

Step Three

The following items were discussed during the meeting with the technical project group and their outcomes are presented in Table 19 below: content of the warm up routine and delivery of the warm up routine.

Topic	Barrier / Issue Raised	Solution
Content of warm up	• Progression criteria for each level of programme • Too many static exercises appeared in the first draft of the programme • Simplification of the instructional text • Consider appropriate regression and progression of the Nordic hamstring exercise at each level. • Include isometric neck strength exercises to address concussion. Multi-directional walking wheel barrow exercises and upper limb plyometric exercise was recommended to be included.	• Teams will be allowed to progress through the programme according to their abilities/preferences rather than at specified progression intervals • Static exercises were incorporated with kinetic chain movement patterns and core stability exercises where possible • Text was simplified using cues and phrases • Hip bridging exercise was used with progression to single leg then Nordic Hamstrings exercises. • Isometric neck strength exercises were included and progressed to multiple planes of movement. Wheel barrow and plyometric exercises were included.
Delivery	• The exercises could be laminated and presented to teams in A4 ring binder. • Warm up routine and training manual could be uploaded to a website allowing coaches access as an additional resource.	• This handout resource was put together and handed out to the teams. • Two websites were set up at the following websites for the respective groups in the study http://rugbyactivate.wixsite.com/2016 http://rugbyactivate.wixsite.com/youth

Table 19: Barriers identified and potential solutions identified by the Technical Project Group.

In step three the feedback from the technical project group, together with the reviewed literature, informed the structure for the programme, which consisted of the following elements:

- Contain a multimodal exercise intervention.
- Include exercise progressions every 4 weeks by increasing volume and / or complexity of exercises.
- The duration of the routine would take up to 20 minutes following familiarisation with the exercise routine.

Additionally, there were amendments to limit the number of static exercises and to encourage a fun element to the routine. A specific example of this was changing the first exercise in the routine from straight running while passing a rugby ball to playing a ball game (such as ‘British Bull Dog’). The expert panel also advised on best practice to include exercises targeting other injury risk factors such as eccentric hamstring muscle strength (Arnason, Andersen, Holme et al. 2008) and neck strength (Hamilton, Gatherer, Robson et al. 2014), based on evidence of their benefits in rugby and preliminary results from a rugby injury prevention exercise programme recently conducted by members of the technical project group (Hislop, Stokes, Williams et al. 2017). In light of the known side effects of the eccentric hamstring exercise, the technical project group advised to regress the exercise to accommodate for this at the youth playing level. The selection of exercises in the updated version of the programme was agreed by the research team, based on their use in other preventative programmes and suitability in a community youth rugby context. The final format of the programme mirrored that of the 11+ (Soligard, Myklebust, Steffen et al. 2008) in its structure by including three parts: running based exercises (part 1), balance, strength and plyometric exercises (part 2) and higher speed running exercises (part 3). These broad categories were then applied to the upper limb and with a rugby-specific focus. Notably, the Nordic Hamstring exercise (Arnason, Andersen, Holme et al. 2008) and isometric neck muscle strengthening exercises (Hislop, Stokes, Williams et al. 2017) were included based on literature demonstrating their benefit in reducing injury risk, despite not having a shoulder focus. The final version of the shoulder IPEP was named the Rugby Activate Shoulder Injury Prevention Programme (RASIP) and is described in

Table 20 below.

Exercise Progressions

The technical project group expressed the need for exercise progressions in the shoulder IPEP, which is in line with current sport injury prevention literature. The lack of exercise progression in the “FIFA 11” was deemed to be a telling factor that resulted in low compliance with the intervention (Grooms, Palmer, Onate et al. 2013). The choice of exercise progressions for the upper limb was decided largely by the technical project group, given that the existing IPEPs had traditionally focused on lower limb injury prevention (Steffen, Andersen, Krosshaug et al. 2010).

The exercise progressions were applied to the strengthening and mobility component (part two) of the programme thereby offering two levels of increasing difficulty for each of the exercises (Appendix A). The exercises were progressed by increasing their complexity, making them more challenging than the previous level. For example, in exercise seven the thoracic spine was mobilised in a four-point kneeling position during rotation of the thoracic spine. This exercise integrated thoracic spine rotation with scapular retraction in level one, which was then progressed to a standing position while extending the thoracic spine. The progression of this exercise incorporated the kinetic chain and involved a deep squatting position, which then included reaching overhead thereby extending and rotating the thoracic spine.

Cautionary advice from the technical project group identified that there was a possibility for participants to experience muscle soreness following the Nordic hamstring exercise. This resulted in the exercise being regressed in level one and two. These regression exercises targeted the gluteal and hamstring muscle groups in a concentric muscle contraction with the aim of developing the participants’ strength in these muscle groups before progressing on to the full eccentric Nordic hamstring exercise. This was completed by participants doing the Nordic hamstring in a more of hip flexed position until they felt confident doing the exercise in a hip neutral position, placing more demand on the hamstring muscle to control the eccentric phase of the movement.

Isometric strength of the shoulder external rotators was prescribed (exercise 9) to facilitate appropriate timing of muscle activation, which was done in a position that recruited the abdominal core stabilisers. The exercise was then progressed to incorporate the kinetic chain in a lunge movement and simultaneous arm movements forming a ‘Y, T, W, L’ pattern. Closed kinetic chain exercises (exercise 10) were also included and progressed from a four-point (limb) base moving forward in a straight line to a two-point base (on hands) in a wheelbarrow position. The wheelbarrow was initially done moving in a straight line and was then progressed to lateral movements as well.

Isometric neck strengthening exercises (exercise 11) were prescribed and progressed from anterior, posterior and lateral resisted movements to then include obliquely resisted forces in level two and three. The upper limb plyometric exercise began at level one with a prone held core stability exercise while a rugby ball was rolled between partners facing each other. In level two, held a push up position and alternated their one hand to tap their other hand in this position. The final progression to this exercise was a clap press up done in a kneeling push up position.

Exercise	Dose
Part 1. Running exercises, 5 minutes total.	
1. Small sided game (British bull dog)	2 minutes
2. Running, Hip out	2 sets
3. Running, Hip in	2 sets
4. Running circling partner	2 sets
5. Running shoulder contact	2 sets
6. Quick running forwards and backwards	2 sets
Part 2. Stability, mobility, strength, plyometrics 8 minutes total.	
7. Thoracic mobility	
Level 1: Four – point kneeling with trunk rotation	3 x 8 – 16 reps
Level 2: Dynamic W Stretch	3 x 8 – 16 reps
Level 3: Squat with trunk rotation	3 x 8 – 16 reps
8. Hip and hamstring strength	
Level 1: Supine hip bridge	2 sets
Level 2: Supine single leg hip bridge	2 sets
Level 3: Nordic hamstrings	3 – 5 reps
9. Shoulder and scapular muscle strengthening	
Level 1: side plank with isometric	2 sets
Level 2: lunge with Y, T, W, L	2 sets
Level 3: lunge with Y, T, W, L	2 sets
10. Closed kinetic chain upper limb stability	
Level 1: Bear crawl	2 sets
Level 2: Wheelbarrow	1 set
Level 3: multidirectional wheelbarrow	1 set
11. Neck strengthening	
Level 1: Isometric neck strengthening	1 set
Level 2: Isometric neck strengthening	1 set
Level 3: Isometric neck strengthening (multidirectional)	1 set
12. Upper limb plyometric	
Level 1: Plank with ball rolling	2 x 10 rolls
Level 2: Push up with horizontal taps	2 x15secs
Level 3: Clap press up	2 x 6 – 8 reps
Part 3. Running, 2 minutes	
13. Running across pitch	2 sets
14. Bounding	2 sets
15. Plant and cut	2 sets

Table 20: The Rugby Activate Shoulder Injury Prevention Programme

Step Four

Participants' responses to RASIP pilot testing highlighted that the wheelbarrow exercise was too difficult. Requiring the exercising player to be held at their ankle level made the exercise too intense. Players were therefore held at their knees, allowing the exercise to be completed effectively. Errors identified with the participants' exercise technique during the trial led the researcher to develop methods of correcting any observed exercise faults. Specifically, this involved observing if the exercise was executed to the desired quality and consistency throughout the routine. Attention was given to the players' movement in effectively completing the exercise. Two to three coaching cues and technical points regarding exercise execution was provided in the training manual resource to support delivery agents in instructing and correcting exercise technique. The players' body alignment during the hip bridge, shoulder side lying plank, wheelbarrow and plank ball rolling were the exercises that players exhibited incorrect technique. During the season coaches were provided with a training resource manual to review the correct technique and given the opportunity to discuss this at follow up visit with the researcher.

Discussion

Minimising the risk of shoulder injuries in rugby is an important direction for injury prevention yet, until now, there has been no attempt to outline and develop a shoulder injury prevention programme in community youth rugby. Traditionally injury prevention exercise programmes have focused on the lower extremity and there has been a gap in the literature of research studies addressing the issue of shoulder injuries in rugby. The preventative shoulder intervention in this study encapsulates research-evidence integrated with expert views and perceptions of end users. This study has responded to current research (Hanson, Allegrante, Sleet et al. 2014) calling for a bottom up approach by engaging practitioners and stakeholders in the process of designing and implementing a shoulder intervention to evaluate it effectiveness.

Current evidence and input from expert practitioners was used to develop a shoulder injury prevention programme for community youth rugby players. Using the structure of efficacious neuromuscular training programmes such as the FIFA 11+ (Bizzini, Junge and Dvorak 2013), provided a useful framework to develop a shoulder-specific intervention and increase its chances of successfully reducing shoulder injuries. In response to the evidence, exercises were selected that did not require equipment to be used, making this intervention practically applicable to a community youth setting where the lack of resources may limit the availability of equipment and deter teams from using the intervention (Emery, Cassidy, Klassen et al. 2005, Emery and Meeuwisse 2010). With this requirement in mind, functional movement patterns that facilitate shoulder function and integrates the kinetic chain were selected which allowed exercises to be combined, thereby also being time efficient. Not requiring any specialised equipment to complete this intervention makes this intervention different to other shoulder-specific interventions that used resistance bands and weighted medicine balls (Ejnisman, Barbosa, Andreoli et al. 2016, Andersson, Bahr, Clarsen et al. 2017).

Designing the shoulder exercises to be functional and to integrate the kinetic chain proved to be useful as this helped address feedback from the technical project group to avoid static standing exercises. The involvement of sport injury prevention researchers in the development process proved beneficial as efficacious findings from their current research contributed to the exercise selection in the shoulder-specific intervention. In addition, their valuable feedback allowed for specific considerations to be made for the target youth population regarding the inclusion of exercise regressions to accommodate for potential known side-effects from certain exercises.

Stakeholders identified that the coach would be the best delivery agent for the IPEP, which was different to findings from a cross-sectional study done with South African rugby players (Brown, Gardner-Lubbe, Lambert et al. 2016). In 2008-2012, Brown et al. (2016) used a questionnaire to assess whether injury prevention behaviours were associated with coach-directed education amongst rugby players (n= 2279 junior and n=1642 senior players) (Brown, Gardner-Lubbe, Lambert et al. 2016). They found that coaches were the preferred source of injury prevention content, acknowledging them as influencers of player behaviour in rugby. This did not, however, hold true for warm up behaviours which players preferred to receive from physiotherapists. It is reasonable to accept that the stakeholders in our study did not recognise physiotherapists as delivery sources of warm up behaviours, reflecting fewer resources available to community youth teams in England. It is worth noting that Brown et al. (2016) assessed a much larger sample of junior players (n=2279), used a different study design (cross-sectional design), and applied a different questionnaire (knowledge, attitudes and behaviour questionnaire) than the current study. In addition, the study was conducted with players participating at a prestigious rugby tournament in a different country, which reflects a different setting and culture. Furthermore, when the benefit of including physiotherapists was evaluated in a cluster randomised trial in female youth soccer players, it was found that there was no additional benefit on adherence for team adherence to the intervention from their involvement (Steffen, Meeuwisse, Romiti et al. 2013). Their findings also suggest that investing time in coaching the coach on the injury prevention exercise programme is effective in subsequent team adherence (Steffen, Meeuwisse, Romiti et al. 2013). Stakeholder feedback in our study to train the coach to deliver the shoulder IPEP is also in line with these findings and other existing research implementation strategies (Bizzini, Junge and Dvorak 2013).

Input from stakeholders was considered to aid the likelihood of successful implementation of the injury prevention exercise programme, to identify delivery methods of the intervention and potential facilitators and barriers to its adoption. The number of stakeholders involved in this step of the process was low and would benefit from more stakeholders participating in future. It was challenging to organise a suitable time for all stakeholders to meet which meant that there needed to be flexibility in the approach to obtaining feedback. Even with flexible options available for the stakeholders to provide feedback, there was a low number of respondents. The shoulder IPEP was further refined following a trial run which informed on the technical aspects around the proper execution of preventative exercises.

Increased opportunities for stakeholder and end users' feedback should be considered in the development of future injury prevention strategies. The scheduling of focus groups to engage the end user and determine the most suitable implementation strategy for preventive programmes needs to be promoted more widely. Community club administrators, regional governing body, coaches and support staff need to play a more active role in prioritising their support and participation in developing injury prevention interventions. An advantage of using focus groups is that they can encourage contributions from people reluctant to be interviewed individually or feel less able to contribute (Kitzinger 1995). In addition, focus groups can capitalise on group interaction, which is useful to explore people's knowledge and experience along with examining why they think that way. These discussions may allow for current warm up practice to be reviewed and replaced with proven methods. There are, however, some challenges with focus groups in terms of managing group dynamics and participants' views being influenced by other group members (Kitzinger 1995). Yet, on balance, future research could extract more feedback from stakeholder and end users using focus groups.

The final step of the development process involved evaluating the acceptability and feasibility of the shoulder IPEP to determine if the exercises could be effectively executed and to identify likely technical faults when doing the exercises. This step also provided feedback on the logistics of how long the exercises would take to complete. Trialling the intervention on a convenience sample of university level rugby players also provided a gauge to determine the appropriateness of the sequence of exercises (Hendricks, den Hollander and Lambert 2019). Technical aspects regarding any unclear or incomprehensible exercise instruction, level of difficulty and faulty exercise technique could be exposed and corrected. It would be advantageous for future studies to further test the intervention by observing if a community youth coach could deliver the warm up to a few players. As the coaches will be trained how to deliver the intervention, it would be worth conducting a trial on training one of the coaches and subsequently observe and review their competency and self-efficacy in delivering the intervention. Following on from the development of this preventative intervention, it will be important to evaluate its effectiveness in a community youth rugby setting to determine if its implementation can be undertaken successfully.

Conclusion

Describing the process involved in the development of the Rugby Active Shoulder Injury Prevention programme can be useful in promoting this strategy amongst stakeholders and provides a useful contribution to understanding the steps necessary in achieving an implementable intervention in community youth rugby. The strength of this study is that it has utilised evidence-based exercise interventions together with practitioner expertise and stakeholder values. This study is the first to provide a detailed account of how a shoulder injury prevention exercise programme has been developed in community youth rugby union. Following this process has subsequently led to the development of shoulder-specific warm up intervention that can be tested in a community youth rugby population.

Chapter Six

The effectiveness of a shoulder-specific warm up programme to prevent injuries in community youth rugby union: a pilot study exploring feasibility and proof of concept.

Background

In chapter five, an injury prevention exercise programme addressing shoulder injuries in youth rugby union was developed using the best available scientific evidence with input from expertise practitioners and consultation with stakeholders. This shoulder injury prevention exercise programme was designed for community youth rugby players and called the Rugby Activate Shoulder Injury Prevention (hereafter referred to as RASIP) programme. As part of evaluating the RASIP programme it is necessary to evaluate the acceptability of an injury surveillance system that is reliable, valid and represents the target audience (Ekegren, Donaldson, Gabbe et al. 2014). Rugby injury surveillance methodologies exist (Fuller, Molloy, Bagate et al. 2007), but a lack of injury data collectors or medical personnel to record injuries in the youth population makes it necessary to consider a clear, coherent and relevant injury data collection approach to enhance efforts to reduce injury (McIntosh 2005). The resources and personnel available at different playing levels in rugby varies and consequently the way in which injury data is collected in an under-resourced environment, such as in community youth rugby, is worth considering an alternative to traditional injury registration methods. Self-reported injury using text messaging has the potential to address the challenges faced in this sport setting and has been described in other sports (Ekegren, Gabbe and Finch 2014, Nilstad, Bahr and Andersen 2014).

The use of text messaging or short message service (SMS) (Ekegren, Gabbe and Finch 2014) is a viable injury reporting method that offers the potential to address some of the identified challenges, as it is relatively inexpensive and has the potential to capture injury data using a customisable system. Previous studies using SMS to report sport injury have been conducted in Danish handball (Moller, Attermann, Myklebust et al. 2012), Norwegian soccer players (Nilstad, Bahr and Andersen 2014) and in Danish school children (Jespersen, Holst, Franz et al. 2014). In the cohort of Norwegian soccer players, prospective injury reporting by medical staff underestimated the incidence of injuries by two-thirds in a seven month soccer season compared to self-reported injuries via SMS, emphasising that text messaging was a feasible registration tool and resulted in much more complete data than medical staff reporting (Nilstad, Bahr and Andersen 2014). The possible reasons for the discrepancy between the individual player and medical staff reporting are worth considering as they may also represent similar issues faced by other under resourced sport teams in the community. For example, the therapist responsible for reporting the injuries was not always present at the training session which, in addition to financial limitations of the sporting league, did not permit every injury to be referred to the therapist. Players may have also wanted to hide their injury from the therapist and not disclose it to be able to continue playing, yet may have still reported the injury using the text messaging system. These factors contributed to a high response rate (90%) using text messaging in addition to fewer barriers to responding, meaning a large player sample could be reached.

Similarly, the use of SMS in elite Danish handball players (Moller, Attermann, Myklebust et al. 2012) resulted in a high weekly response rate of 85%-90%, which is similar to a 96% weekly response rate in Danish schoolchildren (Jespersen, Holst, Franz et al. 2014). The SMS system was considered to limit the risk of recall bias when compared to retrospective studies (Moller, Attermann, Myklebust et al. 2012, Jespersen, Holst, Franz et al. 2014). A critique of using the SMS system to register injuries is that it is determining injury rates based on exposure are dependent on players accurately calculation of exposure times. Nonetheless, when considering the lack of personnel and resources available in community youth rugby, the SMS injury tracking method has shown to be valid, reliable and feasible for participants and injury surveillance researchers (Alfven 2010, Axen, Bodin, Bergstrom et al. 2012).

The feasibility of self-reported injury via SMS has also been evaluated in men’s community Australian football (Ekegren, Gabbe and Finch 2014) where a lack of personnel and resources impedes sustainable injury surveillance to be carried out. A high response rate (90% – 98%) and quick response time (almost half replied within 5 minutes) demonstrated that the players found using the text messaging a convenient method of reporting their injuries. Players reporting injuries reported using SMS received a phone call from the researcher who was a physiotherapist to validate the injury and this process was acknowledged as demanding a substantial amount of work from the researchers in collecting and recording the follow up injury information (Ekegren, Gabbe and Finch 2014). Validating and classifying reported injuries is necessary, though there may be difficulties in reaching the participants by telephone using this method (Moller, Attermann, Myklebust et al. 2012). Other studies have also found similar high response rates. In handball players (n= 517, male and female under 16, under 18 and senior) the response rate was 85% - 90% (Moller, Attermann, Myklebust et al. 2012) and elite soccer players (n=228, elite female) who achieved a 90% response rate (Nilstad, Bahr and Andersen 2014). Using a similar SMS injury surveillance method in a community youth rugby setting would be advantageous to evaluate its acceptability when implemented alongside a shoulder injury prevention exercise programme.

Prior to evaluating the effectiveness of the RASIP programme, it is necessary to explore the acceptability of the intervention in a pilot study, conducted in real-world settings under natural conditions, to identify any barriers and facilitators to implementable action. Reporting these important implementation factors permits consideration of the possible reasons for the outcome of the intervention (Finch 2011). Even when there is an evidence-based preventive measure identified, it may not successfully transfer across settings and contexts. Success or effectiveness of injury prevention is influenced by multiple interdependent contextual factors within specific groups and communities (Hanson, Allegrante, Sleet et al. 2014). Interventions that show preventive benefits in one sport, gender, age group (children/ adolescents/ adults, males/ females) or playing levels (elite/ community) are not always transferable to another target audience or across different national bodies (Finch, Donaldson, Gabbe et al. 2016). Understanding these very specific influencing factors within a particular community youth rugby setting is an important step in establishing preventive interventions and addresses a major knowledge gap of implementation in a community youth rugby setting.

Before meaningful injury prevention is achieved, the determinants and influences of sports safety behaviour need to be understood to enable appropriate and achievable intervention goals to be set (Finch 2011). Reasons for uptake of routine practices of injury prevention exercise programmes such as the RASIP programme, that encompass strength and neuromuscular control exercises, requires adherence of players and coaches. These factors need to be taken into consideration when facilitating its implementation (Keats, Emery and Finch 2012, Emery, Roy, Whittaker et al. 2015). Understanding the constraints and influencers on the intervention outcomes under everyday circumstances will help determine the extent that it actually prevents injuries. Conducting a pilot randomised control trial is an important step to identify the challenges that may hinder the implementation of the intervention (Lancaster, Dodd and Williamson 2004, Feeley, Cossette, Cote et al. 2009, Abbott 2014).

Aims

The aim of this study was to determine the feasibility and acceptability of the RASIP programme.

Study Objectives and approach

a.) To examine the feasibility and fidelity of the shoulder-specific intervention by determining if the study can be executed and intervention delivered as intended. Players' adherence to, and maintenance of, the allocated intervention was also assessed.

b.) To describe the acceptability of the programme by evaluating coaches' and players' attitudes and perceptions towards injury prevention in a community youth rugby union environment.

c.) To assess the mechanisms of recruitment which will be described by investigating any obstacles to recruitment of participants in this study. The administration of data collection forms and questionnaires will be tested to ensure they are comprehensible and appropriate.

d.) To investigate the acceptability of a self-reported SMS injury data collection system alongside a shoulder-specific injury prevention intervention in community youth rugby.

Methods

Participants

Community rugby union clubs in the south of England who had youth teams (n=30 clubs approximately 15 to 20 participants at each club totalling 450 - 600 participants) were contacted by telephone and invited to participate in the study. Players in the under 14 – 18 age groups were eligible for participation in the study. At the same time, social media was used to promote participation via the Twitter platform. The following Tweet was sent out on the 29th September 2016, which included a link to a website landing page hosted by the University of Bath which provided further details about participation in the research project:

the #Rugby Activate Project's rolling out to U15 -U18 teams in Bath and South Glos. Get involved and don't miss out http://go.bath.ac.uk/rugby-warm-up-project …

Twenty-four clubs declined to participate in the study or did not respond to the invitation, which left six clubs that agreed to be involved. Three of the clubs failed to return signed informed consent forms to participate in the study. All participants from three clubs consented to allow their data to be collected, and consent (Appendix B) was obtained from players' parents, with the option for parental opt-out available. (Figure 7).

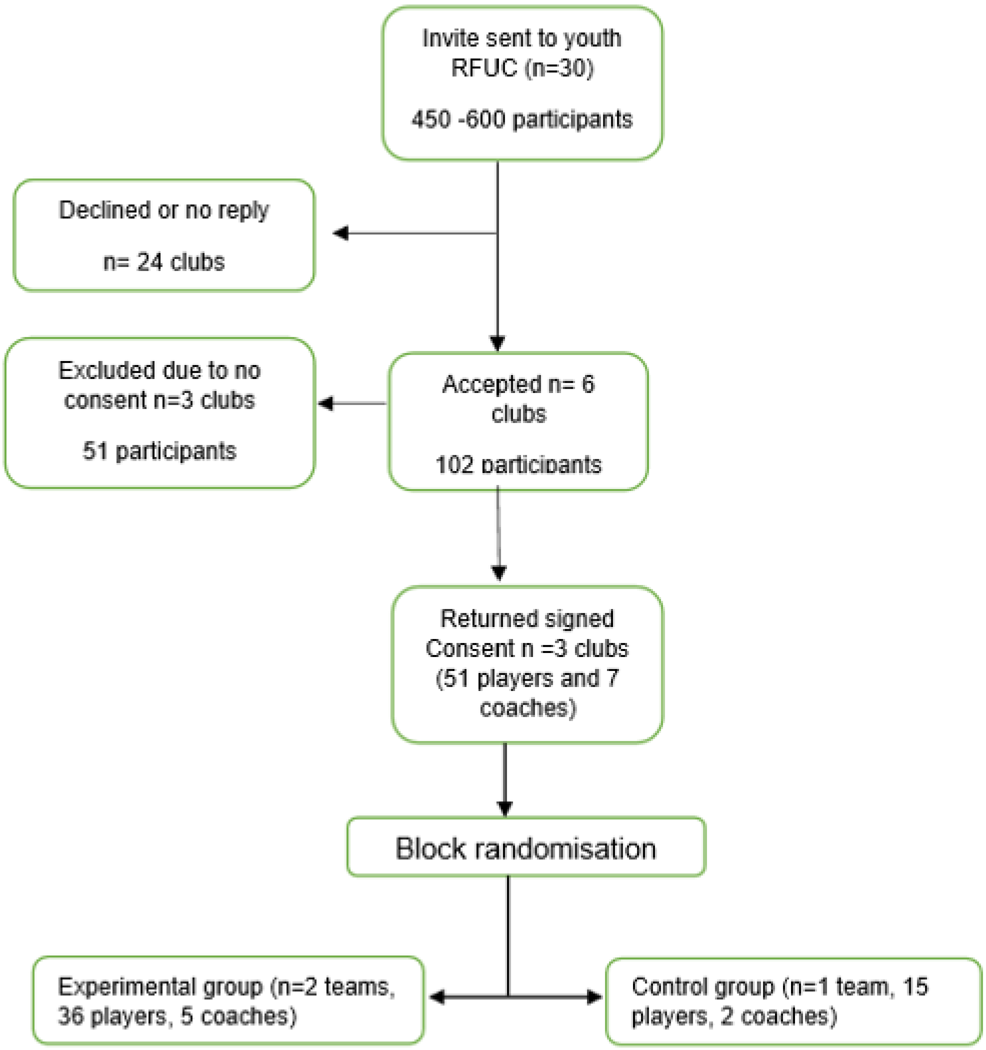

Figure 7: Flowchart of participation through study

Following participant consent, personal data was collected. Clubs and participants were given the right to withdraw from the study in accordance with ethical governance. Anonymity was maintained by allocating individual participants with an alphanumerical code. The research centre and the coach at the club of the participant held the decryption key. Clubs were then randomly allocated to either the RASIP or FIFA 11+ intervention group using block randomisation resulting in two teams allocated to the RASIP group and one to the FIFA 11+ group. The control intervention (FIFA 11+) was selected as it is shown to be an efficacious preventive intervention used within sport. The FIFA 11+ is a neuromuscular training programme which has been successful in reducing injury risk applied across different sports (Longo, Loppini, Berton et al. 2012, Grooms, Palmer, Onate et al. 2013). The "11+" protocol consists of three phases: phase one comprising of six running based drills, followed by six exercises focused on lower extremity strength, balance, neuromuscular control and stability in phase two. Three levels of exercise progressions are included in phase two of the programme. The final phase consisted of three high speed running drills. The design of both programmes evaluated in this study were structurally indistinct in their design with only the content differing. In doing so this allowed for the content of both interventions to be evaluated in regards to the objectives of this study. Ethical approval was obtained from the University of Bath Research Ethics Approval Committee for Health, reference EP 15/16 251.

Procedure for preventative warm up intervention

The lead researcher visited participating teams at the start of the study to deliver an induction to the warm up intervention and discuss the reporting paperwork required from the coaches. Regular periodic contact was maintained face to face or over the telephone during the study period. All teams were provided with educational resources in a folder that included laminated colour sheets of paper that provided pictures and instructions for each exercise. The coach at each club was also tasked with completing a weekly reporting form that included details about completion of the warm up routine and injuries sustained during weekly matches (Appendix C). This enabled team adherence with the intervention to be evaluated against study objective (a). Additionally, a website was created that provided all the educational resources and a training manual for all the exercises. The detail in the training manual covered aspects of correct technique for each exercise and highlighted key coaching points.

Coaches and players attitudes

Coach adherence was defined as the overall proportion of exercises completed during the programme (reported by the coach) that was completed at the team level across all exposures. The teams were visited twice during the intervention to observe whether they completed the warm up routine and to specifically record the number of exercises done at that session. It was not possible to visit the teams unannounced due to the variation of training days and locations for some teams and therefore visits needed to be coordinated with the coaches. A SMS was sent to the players' parents following these observational visits requiring them to reply 'yes or no' if they did the warm up programme. If they replied 'yes' they were sent another SMS to find out how many exercises were completed at that session, which was compared to that reported by the researchers at the observational session and with the coaches' reporting form (main measure for verification). This process was done to test the reliability of the coach reporting. As the players in this study were under 18 years old, the Rugby Football Union Safeguarding policy, best practice guidance was followed. It states that *"messages relating to children, sent via telephone, emails and texts, should be through their parents/ guardians".* The intervention's feasibility was also qualitatively reported by observing the method of delivery demonstrated by the delivery agents in their approach to engage with and deliver their allocated programme (Feeley, Cossette, Cote et al. 2009).

Coaches' and players' attitudes were assessed using an online questionnaire through the Online Survey software (formerly Bristol Online Survey) pre- and post-intervention. This was adapted from a questionnaire created to use with youth soccer coaches (McKay, Steffen, Romiti et al. 2014). The questions were re-phrased to reflect a rugby playing population and underwent face validation (checking and agreeing that the questionnaire is a valid measure of the concept which is being measured) by the research team prior to the start of the study. The questionnaire captured information about the coaching and player experience in section A, perceptions and attitudes towards injury risk in rugby in section B, and feedback about the rugby-specific warm up routine was asked in section C. The questions were formatted to differentiate the coaches' and players' roles' with polychotomous and seven-point Likert scale response to all questions. After the intervention, coaches' and players' perceptions and attitudes towards using their allocated programmes were captured using an online form. The pre and post-intervention questionnaire is included in Appendix D. In order to address outcome (b) the coaches' attitudes were described descriptively by identifying common themes in the responses.

The Online Survey is an online service licensed by the University of Bath and allowed the development, deployment and analysis of this survey via the internet. Once the survey was set up using the Online Survey software, a link to the survey was embedded into a mail merge email to all coaches and players' parents for them to complete. Each participant was allocated an anonymised code together with their email address which was used to create the recipient list on the Online Survey system. The key to the coding used was stored on a password protected computer by the researcher.

Injury surveillance method

The injury definition used was the “all complaints” definition, which was an injury that results from the player’s body’s inability to withstand a transfer of energy during rugby, irrespective of the need for either medical attention or time-loss from rugby activities. To further define this injury definition, injuries that affected the player from playing or stopped them from playing were reportable. The method of injury reporting used in this study was self-reporting by the players (parents) using short message service (SMS). Text messaging was used to extract as much information about the injury as possible tailoring specific automated questions sent to the participants. Participants received a SMS 1-2 days after each match which read: ‘Message from the Rugby Activate Project (University of Bath): Did your son play in a match for his rugby club on the weekend? Reply: “1” for Yes or “2” for No’. If the response was ‘yes’ the following message was sent: Did your son get injured during the match? (any injury that affected his ability to play or stopped him playing?) Reply: “Yes” or “No”. If the participant experienced an injury by replying ‘yes’ he received a follow-up SMS. If the participant did not reply to the initial SMS they received another SMS 2 days and 4 days after the initial attempt. The SMS enables the injury to be described in the following categories; date of injury, mechanism of injury, body region injured, nature of injury, initial treatment, action taken, referral, provisional severity assessment, treating person and return to training date. The flowcharts below (

Figure 8, Figure 9, Figure 10, Figure 11) illustrates the structure of the text message sequence and triggers that were followed:

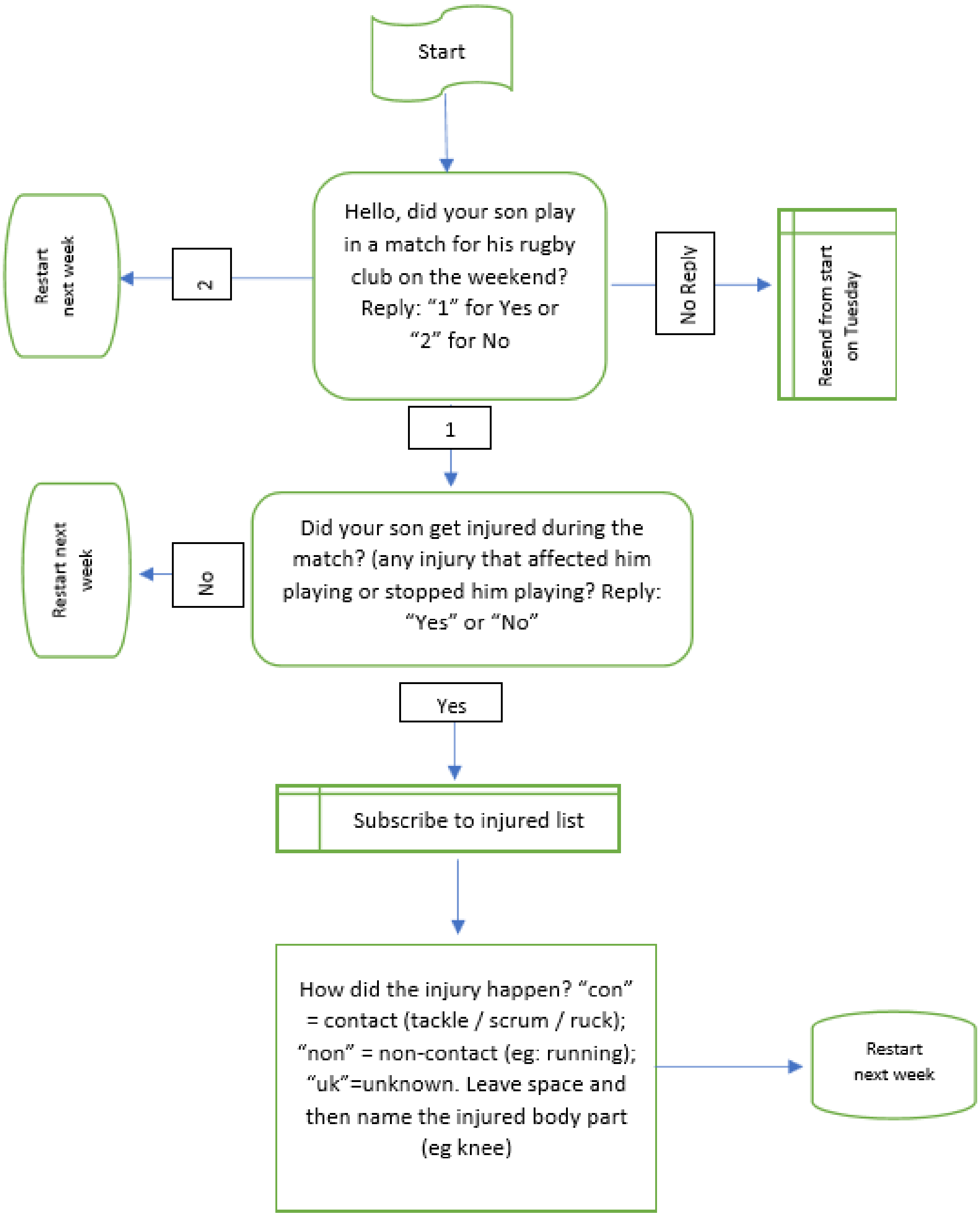

Figure 8: Text message sent on the Monday to players' parents on non-injured list following a match played 24 hours ago

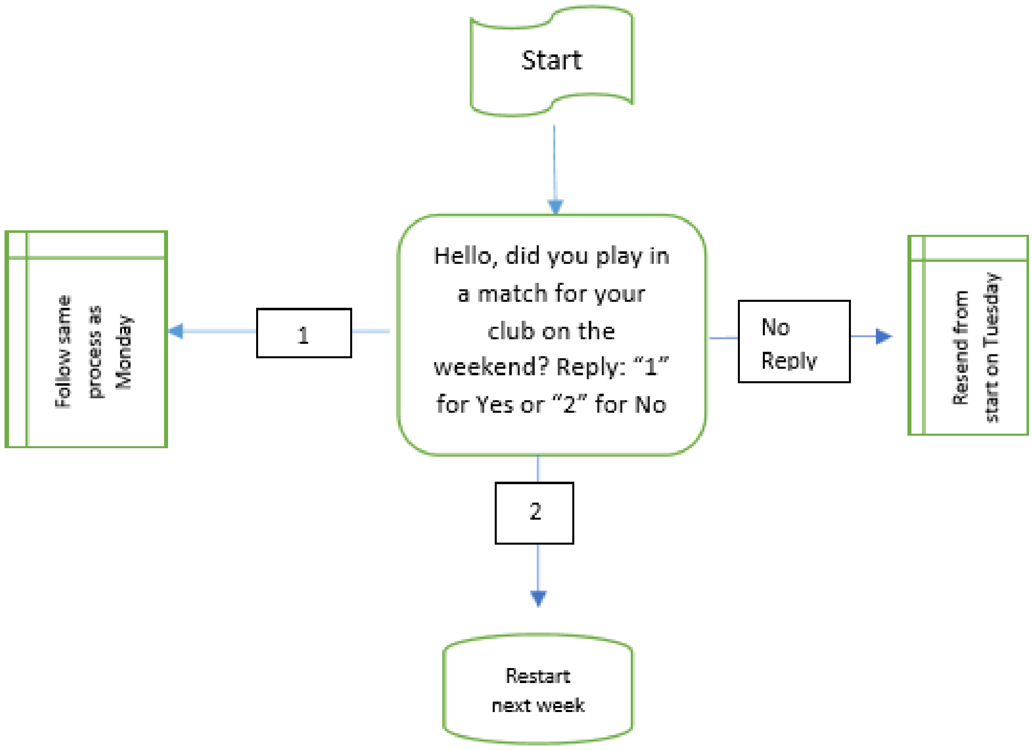

Figure 9: Text message sent on Tuesday to those players' parents who did not respond to initial text message.

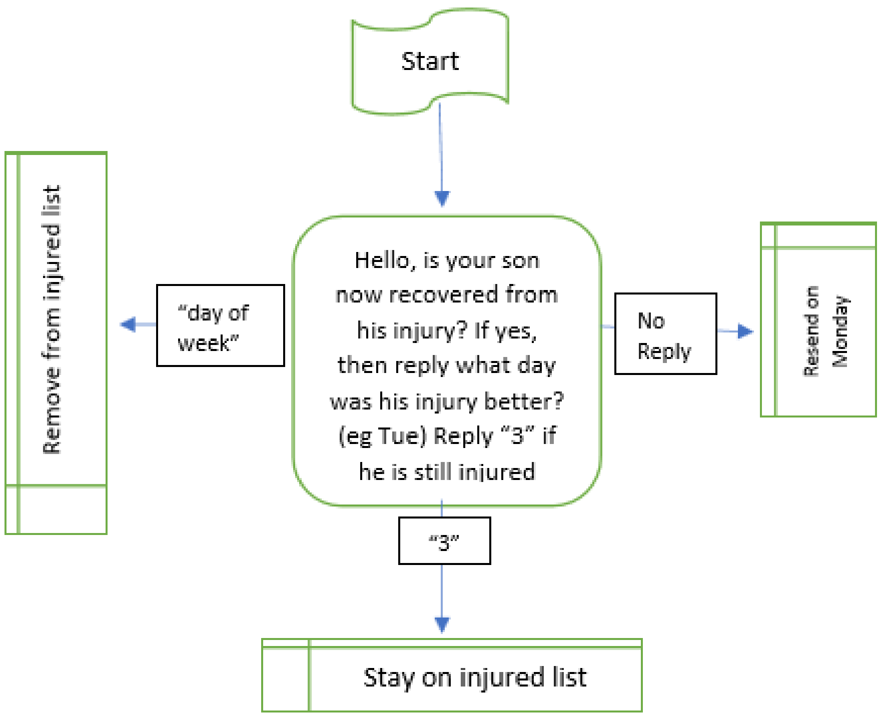

Figure 10: Text message sent on Friday to follow up with injured players' parents

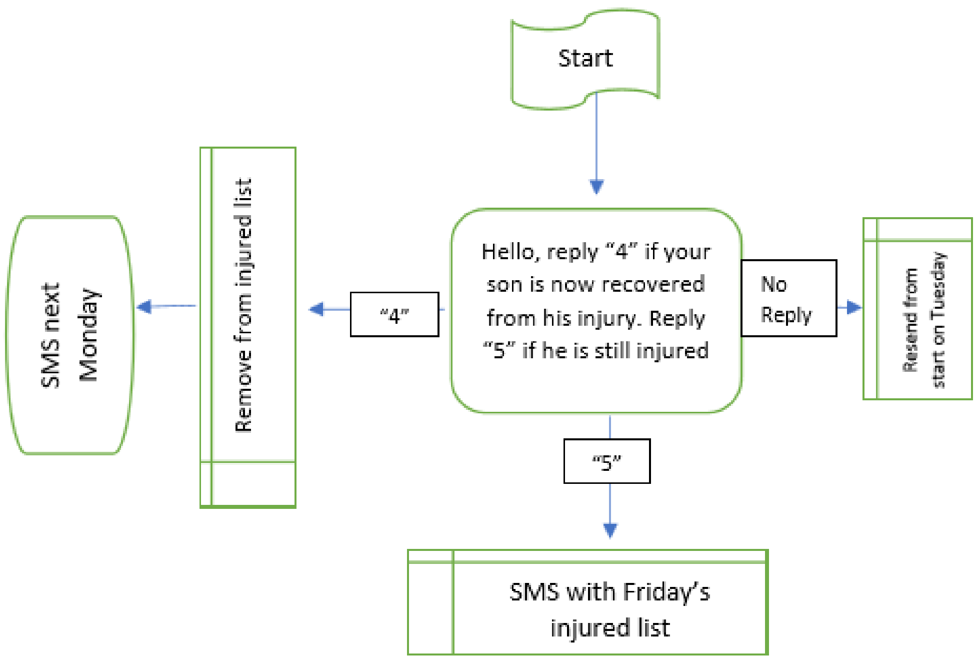

Figure 11: Text message sent on Monday to follow up with injured players' parents

Analysis of results

Feasibility was evaluated by describing the reach of the intervention which was determined by reporting the number of eligible people in attendance and participating in the intervention, which was measured weekly as a percentage of the total cohort of players consented to the study, objective (a). Additionally, the intervention feasibility was assessed by describing the recruitment and retention of participants to the study, also including obstacles to recruitment, objective (c).

Measures of fidelity in the intervention delivery was recorded weekly at the team level by the coach or designated player. This was determined by the proportion of exercises completed for each group which was calculated by the total number of exercises completed during the study, divided by the total number of exercises that could be completed, objective (a). The duration taken to complete the programme was also used as an assessment of fidelity, objective (a). Additionally, the method of delivery of the intervention was also reported descriptively for each group.

Questionnaire

Thematic analysis was used to analyse the coaches' and players' pre-post responses to the online survey, objective (b). Firstly, the data was read analytically to become familiar with the content and ideas presented. The responses were reported descriptively under the following categories; injury risk awareness and outcome expectations, and feedback about the warm up routine, separately for both coaches and players. Coding was then applied to identify themes allowing for the coaches' and players' responses to be described as perceived barriers and facilitators to the implementation of the warm up routine. The questionnaire data was then described by identifying a combination of semantic and latent, and inductive elements (Smith and Sparkes 2016).

Self-reported injury

Evaluating the acceptability of injury self-reporting via SMS enabled objective (d) to be achieved. In order to do this, the following outcome measures were assessed: response rate to the first SMS question sent and then to the follow-up question sent to non-responders, duration to respond, necessary time, resource required and descriptively capturing any barriers to using the SMS system. Fastsms (trading name for Commify UK Limited) was the SMS internet service provider used in this study.

Match Exposure

Players were sent weekly text messages (*Figure 8*) asking if they had played in a match on the weekend. This information was used to calculate weekly group match exposure which was determined by the number of matches x number of players per team x match duration (hours) (Fuller, Molloy, Bagate et al. 2007). This exposure was used for both the coach reported and self-reported exposures. The incidence of injuries per season is calculated, with injury incidence documented as the number of time-loss injuries per 1000 player hours of match exposure. The results from this evaluation addressed objective (d) in terms of describing the injury epidemiology.

Results

Recruitment

The recruitment flowchart in *Figure 7*, illustrates that out of a potential 30 clubs, six accepted our invitation to participate in the study. A further three clubs were excluded due to not providing consent to participate in the study, resulting in the remaining three clubs being block randomised into the intervention (n=2 clubs, 36 players and 5 coaches) or control group (n=1 club, 15 players and 2 coaches).

Coach and player baseline characteristics

Of the 51 players participating in the study, 21% (11 out of 51) of them completed the pre-intervention questionnaire which was similar to the percentage of coaches 28% (2 out of 7, one from each group) that completed the coach version of the pre-intervention questionnaire. Six out of 36 players in the RASIP group and five out of 15 players in the control group (FIFA 11+) completed the pre-study questionnaire (total, n=11). There were slightly fewer players and coaches completing the post-intervention questionnaire with 17% and 25% respectively. A coach from the RASIP routine visited the website twice, which was set up with a detailed training manual.

Baseline Coach Characteristics

Table 21 below describes the coach demographic details and their experience with conditioning interventions.

Question	**RASIP (n=1)**	**FIFA 11+ (n=1)**
1. Coaching experience	7-9 years	7-9 years
2. Coaching level	School/ club	School/ club
3. Level coached last season	School/ club	School/ club
4. Hours of coaching per week last season	5 hours	4 hours
5. Previous experience of using conditioning programme to improve performance	Yes	No
6. Previous experience of using conditioning programme to reduce players' risk of injury	No	No

Table 21: Coaches' rugby participation and injury history

Players' baseline characteristics

Most players (64%, 7 out of 11 players) had 7 – 9 years of playing experience, 9% had played for 4 -6 years, 18% (2 out of 11 players) played for 1 – 3 years and 9% (1 out of 11 players) had less than a year experience playing rugby. Most players (73%, 8 out of 11 players) played for their schools and at club level while 27% were playing at academy level. On average 9% of players participated in 6 hours of rugby per week, most players (36%) were averaging 5 hours, while 27% (3 out of 11 players) reported taking part in 4 hours per week. There were 18% (2 out of 11 players) completing 3 hours per week and 9% (1 out of 11 players) played 2 hours per week. A high percentage of players (91%, 10 out of 11 players) had no experience of using a specific performance enhancing conditioning programme while 9% (n=1 in the FIFA 11+ group) had done a conditioning programme while playing at academy level. A similar trend was seen with players using a conditioning programme to reduce risk of injury with 91% (10 out of 11 players) having never done one before and 9% (n=1 in the RASIP group) of players had done this type of conditioning before.

Player participation

The average weekly attendance across the season was nineteen out of 36 players (53%) in the RASIP group while on average all 15 players (100%) were in attendance in the FIFA 11+ group. The majority of those players attending, participated in the full programme during training and before matches. Participation for the FIFA 11+ group ranged from 88% -100% while the RASIP group ranged from 95% - 100% over the 12 weeks of the intervention (Figure 12). The average for the both groups was 99% for attending players participating in the warm up routine.

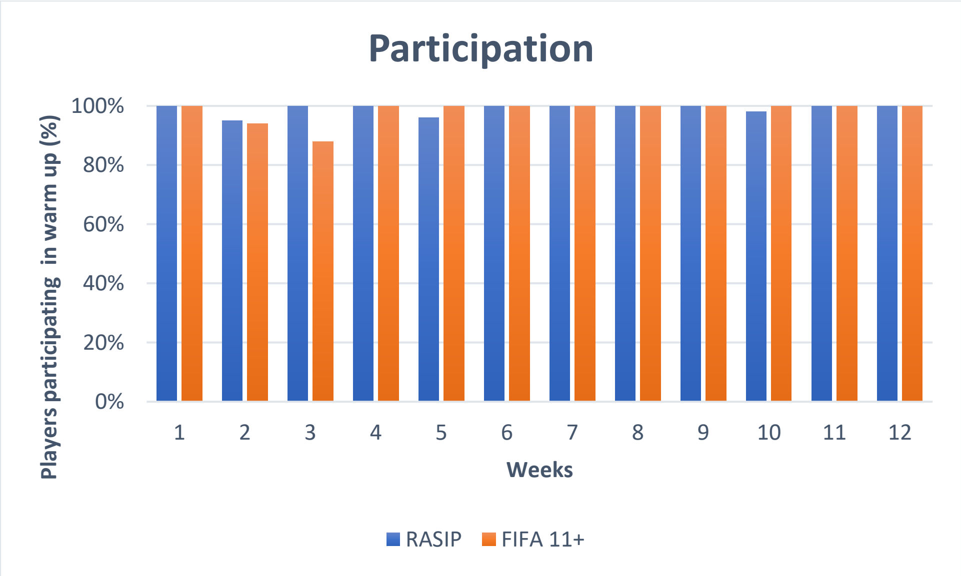

Figure 12: Participation percentages during the 12-week intervention

The FIFA 11+ group completed a higher proportion of exercise (291 out of 300 exercises, 97% adherence) compared to the RASIP group (261 out of 450 exercises, 58% adherence). The observed training session reported by the lead researcher was similar to the coach reported values for the FIFA 11+ group but was different for the RASIP group (Table 22). The players used SMS to report the number of exercises they completed during the training session in Table 22. The mean duration taken to complete the FIFA 11+ routine was 24 minutes which was higher than the mean duration (15 minutes) of the RASIP group (Cohen's *d* effect size -2.5).

Reported Adherence	**Group**	
	RASIP	**FIFA 11+**
	(sample variance)	
Coach reported (all sessions)		
Number of participants (mean)	19 (16)	15 (4)
Number of exercises completed (total)	261 (3)	291 (2)
Percentage of exercises completed	58%	97%
Warm up duration (minutes) mean	15 (15)	24 (11)
Observed by researcher		
Number of participants (mean)	18 (40)	15 (4.5)
Number of exercises completed (total)	43 (4)	30 (0)
Percentage of exercises completed	72%	100%
Warm up duration (minutes) mean	17.6 (12)	25.5 (85)
SMS reported (participant)		
Exercises completed (mean)	9	12

Table 22: Adherence to warm up routine

Two of the teams, one team doing the RASIP warm up and the team doing the FIFA 11+ warm up, had the intervention delivered by their coaching staff while one team in the RASIP group allocated a player 'champion' responsible to deliver the warm up routine.

In the FIFA 11+ group, an average of 97% of exercises were completed during the first 4 weeks while 100% were completed during the last 4 weeks. The percentage of exercises completed by the RASIP group was 50% and 61% during the first and final 4 weeks of the intervention respectively. There was more variation in the selection of exercises completed weekly in the intervention group compared to the control group as indicated by the exercises marked off on the weekly reporting forms. In addition, feedback from the coaches revealed that, due to time restraints, within their session they chose the exercises which they believed to be best for the type of session they were running that day.

Method of intervention delivery

Across all teams in both groups there were different approaches followed in delivering the allocated intervention. When observed, the coach delivered the intervention in the control group, adhering to the sequential order and precise dosage of exercises as they appeared in the programme. Both teams in the intervention group did not complete all exercises prescribed in the intervention with some exercises only done sometimes but not always during their weekly sessions.

Coaches' injury risk awareness and outcome expectancies

The coaches' intent to complete the warm up routine was rated as "extremely good" (rated 7 out of 7 by both coaches) prior to starting the study and at the end of the intervention, with an expectation that the players would be "quite and extremely likely" to improve (6 to 7 out of 7) their skill by doing the warm up routine. In addition, the coaches responded that the warm up routine would be "extremely good" at reducing the players' risk of injury. It was anticipated by the coaches that the warm up routine would be "extremely and quite pleasant" to complete, with an expectation that the warm up routine would be fun.

Both coaches said that it was "extremely likely" that their players would sustain an injury during the season and that it was a shared responsibility between the coaching staff, players and referee to prevent injuries from occurring. At the outset of the study the coaches perceived their role in injury prevention to be ensuring player fitness, recovery and preparation for the match. Poor muscle strength, a lack of skill and poor technique were considered to be the contributing factors to injuries occurring.

The coaches thought that injuries to the face and head was most common at the start of the study; however, on completion of the study they believed that injuries to the shoulder and arms, or knees and ankles were the most common injuries in the RASIP and FIFA 11+ groups, respectively.

Feedback about the warm up routine

On average, based on the coach reported data, the coaches completed the warm up routine 2 -3 times per week. The coaches felt that doing the warm up routine left them with little time to do other rugby skills training in the FIFA 11+ group. The RASIP exercises were not perceived to be specific enough and the coach thought routines could include exercises that involved a contact element such as grappling. The coach in the RASIP group liked the idea that by doing the routine they learnt exercises that may reduce injuries to their players while the coach of the FIFA 11+ group liked that their players got better at doing the exercises.

Players' injury risk awareness and outcome expectancies

At baseline all 11 players felt that completing the warm up routine would be "good", which did not change by the end of the study for the FIFA 11+ group though 20% (1 out of 5 players) of players in the RASIP group expected that it would be "unpleasant" There were more players in both groups who said that "a boring and repetitive warm up routine would be bad", as highlighted by 40% of players (2 out of 5 players) in the RASIP group and 100% in the FIFA 11+ group by the end of the study. Initially all players agreed that "having fun with their team would enable them to complete a rugby specific routine", which was the same at the end of the study for the FIFA 11+ group; however, in the RASIP group 40% (2 out of 5 players) disagreed and thought the opposite. A high percentage of players (66%, 4 out of 6 players) in the RASIP group believed that a warm up routine would improve their physical conditioning while 33% (2 out of 6 players) felt that it would be "slightly unlikely" to have this effect. At the end of the study, 80% of players (4 out of 5 players) in the RASIP group believed that the routine would improve their conditioning. All players in the FIFA 11+ group felt that a warm up routine would improve their conditioning at baseline, while 25% (1 out of 4) felt that this was "slightly unlikely" by the end of the study.

At baseline, all players who completed the questionnaire expected that they would sustain an injury during the season, which was the same response at the end of the study. The players in the RASIP group (50%, 3 out of 6 players) thought that injuries to the head and face, and shoulders and arms were the most common injuries in rugby with injuries to the knees and ankles being most common. The FIFA 11+ group said that head and face, chest and abdomen, and injuries to the lower body (hamstring and thigh, pelvis and hips) were most common. All players apart from 1 in each group at baseline believed that injuries are preventable. This was the same at the end of the study, apart from the FIFA 11+ group where all players thought that injuries were preventable. It was a common view that coaching staff, players, parents, referees and medical staff were responsible for preventing injuries. A lack of skill, poor technique, and inadequate warm up were identified by both groups as factors that contribute to injuries in rugby. In addition, 60% (3 out of 5 players) the FIFA 11+ group said that body contact was a contributing factor to sustaining an injury. These factors were also reported by the groups at the end of the study, as was a lack of fitness or training, poor strength and flexibility and player aggression and tackling risk. Furthermore, the players' said that ensuring they completed a proper warm up routine, were adequately recovered and ate healthily are things that they could do to reduce their risk of injury.

All players in the FIFA 11+ group felt that decreasing their risk of sustaining an injury would be “good” while 33% (2 out of 6 players) in the RASIP group felt that it would be “slightly bad” at baseline. At the end of the study this reduced to 20% (1 out of 5 players) in the RASIP group saying that it would be “bad”, while 25% (1 out of 4) in the FIFA 11+ group thought that it was “quite bad” to reduce their risk of injury. A similar trend was seen with players’ expectations of a warm up routine reducing the risk of injuries with 17% (1 out of 6 players) in the RASIP group thinking that it would be “quite unlikely” to reduce injury at baseline. All players in the FIFA 11+ at baseline believed warm up routine would reduce their risk of sustaining an injury, however at the end of the study 25% (1 out of 4 players) of the FIFA 11+ group believed that it would be “quite unlikely” to reduce injury.

SMS Response rate

The average response rate to the first SMS message sent every Monday during the study was 73%, which increased to 82% after the follow up message was sent on Tuesday. Participants’ responses to the first message were on the same day as message was sent. Follow up messages sent to non-responders were typically replied to on the same day it was sent or the following day.

Injury trends

Coaches completed the injury reporting weekly and SMS was used to collect self-reported injury data (table 24-26). The self-reported injuries using SMS captured a higher incidence of all injuries [63 per 1000 hours (n=24, 95% CI: 37 to 89)] for both groups than the coach reported injuries [41 per 1000 hours (n=15, 95% CI: 20 to 62)]. The self-reported incidence of injuries was similar for the FIFA 11+ group with 60 injuries per 1000 player hours (n=6, 95% CI: 12 to 108) compared to 68 injuries per 1000 player hours (n=18, 95% CI: 37 to 100) for the RASIP group using SMS. The coaches in the RASIP group reported 11 injuries per 1000 player hours (n=3, 95% CI: 0 to 24) and the FIFA 11+ group reported 120 injuries per 1000 player hours (n=12, 95% CI: 52 to 188), as presented in Table 23.

	Number of injuries (n=)	Player Matches	Player Match hours	Injury incidence Per 1000 hours	95%CI
All					
SMS	24	273	363	63	26 (37 to 89)
Coach	15		363	41	21 (20 to 62)
RASIP					
SMS	18	198	264	68	31 (37 to 100)
Coach	3		264	11	13 (0 to 24)
FIFA 11+					
SMS	6	75	100	60	48 (12 to 108)
Coach	12		100	120	68 (52 to 188)

Table 23: Match exposure, injury incidence during the 12-week rugby warm up routine.

Overall, injuries to the torso and groin had the highest incidence 40 per 1000 player hours, (95% CI: 1 to 79) in the FIFA 11+ group, and lower limb injuries (38 per 1000 player hours, 95% CI: 14 to 61) were most common in the RASIP group, based on SMS data

Table 24). The most common coach reported injury was to the torso and groin in the FIFA 11+ group (50 injuries per 1000 hours, 95% CI: 6 to 94), while there were no injuries to this body location reported in the RASIP group. A different spread of self-reported injuries to this region were reported for the FIFA 11+ group (40 injuries per 1000 hours) and 8 injuries per 1000 hours for the RASIP group.

Injury Type	Incidence				All injuries per 1000hrs	95% CI
	FIFA 11+	95% CI	RASIP	95% CI		
			Upper Limb			
SMS	10	20 (0 to 30)	11	13 (0 to 24)	11	11 (0 to 22)
	(n=1)		(n=3)		(n=4)	
shoulder	10	20 (0 to 30)	4	7 (0 to 11)	6	8 (0 to 13)
	(n=1)		(n=1)		(n=2)	
Coach	0		0		0	
	(n=0)		(n=0)		(n=0)	
			Lower Limb			
SMS	0		38	23 (14 to 61)	25	15 (9 to 40)
	(n=0)		(n=10)		(n=10)	
Coach	30	34 (0 to 64)	4	8 (0 to 12)	11	11 (0 to 22)
	(n=3)		(n=1)		(n=4)	
			Torso and Groin			
SMS	40	39 (1 to 79)	8	10 (0 to 18)	17	13 (3 to 30)
	(n=4)		(n=2)		(n=6)	
Coach	50	44 (6 to 94)	0		14	12 (2 to 26)
	(n=5)		(n=0)		(n=5)	
			Head			
SMS	10	20 (0 to 30)	11	13 (0 to 24)	8	8 (0 to 16)
	(n=1)		(n=3)		(n=4)	
Coach	40	39 (1 to 79)	8	11 (0 to 19)	17	14 (3 to 31)
	(n=4)		(n=2)		(n=6)	

Table 24: Type of Match Injury during 12-week rugby warm up routine (SMS and coach reported data)

Self-reported contact injuries using SMS accounted for the greatest number of injuries (n=15) compared to non-contact (n=4) and those of unknown origin (n=5) (Table 25). There were more self-reported injuries reported for contact (n=6), non-contact (n=3) and unknown (n=6) than coach reported injuries.

Injury Event	Incidence of All injuries (per 1000 player hours)	Upper limb	Lower limb	Torso and Groin	Head
Contact					
SMS	41 (n=15)	(n=3)	(n=5)	(n=3)	(n=4)
Coach	17 (n=6)			(n=1)	(n=5)
Non-contact					
SMS	11 (n=4)	0	(n=4)	0	0
Coach	8 (n=3)		(n=2)		(n=1)
Unknown					
SMS	14 (n=5)	(n=1)	(n=1)	(n=3)	0
Coach	17 (n=6)		(n=2)	(n=4)	

Table 25: Injury type with associated match event (total)

Discussion

Until now, no other study has attempted to address shoulder injury prevention in community youth rugby union players. This pilot study evaluated player adherence to a shoulder injury prevention exercise programme (RASIP) compared to a lower limb focused routine and found that youth rugby teams adhered better to the latter (FIFA 11+) preventative exercise routine. Coaches' and players' attitudes towards injury prevention was also explored to understand these components to bridge the gap between research and practice in determining successful injury prevention implementation and enhance real-world impact. Supporting coaches to improve their self-efficacy in delivering the injury prevention exercise programme is an important consideration to enhance adherence to the intervention at this playing level. Additionally, assisting coaches in scheduling the preventive intervention into their training sessions would address their recognised concern regarding the limited time they have available to include the additional injury prevention exercises. The high response rate, 73% and 82% to the first and follow up text message respectively, for self-reported injuries in community youth players supports this method as a feasible option to injury surveillance in a larger study.

The feasibility and fidelity of the warm up routine which showed that the percentage weekly attendance and average number of exercises completed weekly was higher for the team completing the FIFA 11+ warm up routine than the RASIP warm up routine (89% versus 53% and 97% versus 58%, respectively). Reasons for players not attending sessions during the study period were not given and it cannot be concluded that this was due to lack of engagement with either of the injury prevention exercise programme. At baseline, seventeen percent of players in the RASIP group expected that the routine would be unpleasant and also did not think that the warm up routine could reduce their risk of injury. The lower average number of exercises completed in the RASIP group does suggest that the programme or the delivery agents for this routine did not encourage the players to adhere fully to that programme.

When measuring player adherence to the routine, it is also relevant to consider how sessions were delivered to the teams which could have influenced this outcome. It was intended for the coaches to deliver the sessions but variation existed in the method of delivery of the intervention across all teams. One of the teams in the RASIP group had the warm up routine delivered by a team champion while the other two teams had coaches as delivery agents, with both coaches displaying different approaches to delivering the exercises in the intervention. One of the coaches in the FIFA 11+ group stuck to a prescriptive delivery of the programme while the other coach in the RASIP group was more selective of the exercises their team completed. Unsupervised delivery of a warm up routine has been shown to lead to reduced adherence in the first study done on footballers (age 13 to 18 years) to evaluate methods of delivery for the 11+ warm up routine (Steffen, Emery, Romiti et al. 2013). Their study showed that coach led warm up routines with or without support from the team physiotherapist showed that groups performed almost twice as many exercises as players in teams where the delivery was unsupervised. When the players' preferred delivery source of injury prevention education was evaluated in rugby, in comparison to junior players, the majority of senior players gave specific preference to receive information about warming up from physiotherapist and not coaches (Brown, Gardner-Lubbe, Lambert et al. 2016). These two studies suggest that the source of preventive education may change amongst playing age groups however this may also reflect a lack of resources available to the teams at community youth playing levels where it is not feasible to offer physiotherapy services at this level of the intervention delivery. In the future, it is reasonable to propose that the injury prevention exercise programmes are prescriptively delivered by the coach so that a higher number of exercises can be completed.

Success of preventative interventions depends on these training programmes being incorporated into regular training which requires positive attitudes and beliefs from coaches towards injury prevention (White, Otago, Saunders et al. 2014). A recent systematic review was the first to focus on the specific implementation components of team ball sports using injury prevention exercise programmes (IPEP) (O'Brien and Finch 2014). In the studies they reviewed, high adherence was attributed to the IPEP being incorporated into team training. In contrast, low adherence was reported in teams that performed the IPEP in addition to team training. The coaches in the present study had strong positive attitudes towards injury prevention, suggesting that they would be receptive to integrating the shoulder injury prevention exercise programme in their training sessions in future. This would better equip coaches with the skills to be confident delivery agents. In addition, the coaches found that the RASIP exercises were not specific enough and they would have liked a contact element such as grappling included. This form of training did not appear in the literature during the review process and was not proposed by the technical project group to justify its inclusion, and it is unclear if this would have contributed to better adherence to the intervention.

Also, the players said that ensuring they completed a proper warm up routine was something they could do to reduce their risk of injury. Despite players believing this, it did not persuade the RASIP group to complete the exercises in full. This is not an uncommon finding, as low compliance to the evidence-based Nordic Hamstring routine has been seen in a retrospective survey amongst elite Champions League and Norwegian Premier League football teams (Bahr, Thorborg and Ekstrand 2015). The authors found that there was no relationship between non-compliance and other personal factors, leading them to propose other reasons for non-compliance such as limited influence by the medical team. Interestingly, though players in the 11+ group in the present study found the routine to be boring and said that it detracted them from practicing other rugby skills, they still completed all the exercises in the routine delivered by a coach that prescriptively followed the programme. In community youth rugby teams where there is a lack of medical support, a coach-led and prescriptively followed injury prevention exercise programme was better at achieving higher adherence with exercises compared to a player led warm up routine.

When players attended the sessions, their weekly participation in the respective interventions was high (99%) for both interventions. An interesting finding was that rather than players dropping out at the end of the study, there were more players attending the sessions. This may be due to players being able to balance their school and other commitments better during this part of the season. These findings are in contrast to the attrition rates seen in compliance in a systematic review of 52 intervention injury prevention trials (O'Brien and Finch 2014). The exact reasons for more players turning up is unknown. Gaining a better understanding of this outcome in future studies is important for sustained behaviour change.

A discrepancy was seen between the two injury registration methods in favour of the self-reported method in terms of the number of injuries recorded. More injuries were captured using the SMS injury surveillance method (n=24) compared to those reported by the coaches (n=15). There were different injury types seen with self-reported injuries compared to those reported by the coach. This was most apparent for lower limb injuries where none were reported using SMS for the FIFA 11+ group, while the coach reported 30 injuries per 1000 player hours (n=3) in this group. The opposite of this was seen in the RASIP group for the same injury location, where the coach reported fewer injuries (n=1) compared to those self-reported (n=10). Further inconsistencies were seen with more coach reported head (40 per 1000 hours, n=4; 95% CI: 1 to 79) and torso and groin injuries (50 per 1000 hours, n=5; CI: 6 to 94) compared to self-reported injuries (10 per 1000, n=1; 95% CI: -10 to 30 and 40 per 1000 hours, n= 4; 95% CI: 1 to 79, respectively). Considering that there was also some coach reported injuries that were not recorded using the self-reported method, it is acknowledged that both registration methods using the "all complaints" injury definition have their limitations with coaches' substantially under-reporting injuries. Injury data reporting for the coaches during training may have been too onerous a task for them to complete and consequently this method did not capture the entire spread of injuries. Other research studies have also shown discrepancies with medical staff missing more than half of all injuries compared to self-reported SMS reporting injuries (Nilstad, Bahr and Andersen 2014). Solely using coach reported injuries may present an inaccurate incidence of injuries amongst this population. Due to the difference in injuries reported using both injury registration methods in this study, conclusions cannot be drawn on which method is better or worse. Further research with a larger sample size is recommended to determine which method would be best suited to community youth rugby.

The "all complaints" injury definition used in the current study is subject to systematic bias due to the interpretation of what constitutes a reportable complaint. To try and minimise this problem occurring, injuries that affected the player from playing or stopped them from playing were reportable. Only a limited amount of information relating to the injury can be collected from the players who were not expected to be able to reliably report detailed diagnostic information. Both the coach reported and self-reported injuries in the current study were not objectively verified by a medical professional to determine the reliability and validity of the injury. In order to obtain diagnostic information and accurately diagnose the injuries, follow-up by trained medical staff is required. Using medical staff to diagnose injuries is not feasible in the community youth rugby context due to a lack of resources.

Understaffing of teams in community level sport is a recognised limitation to injury surveillance and is a challenge faced by community youth rugby teams in our study. The use of the text messaging service offered a quick method for self-reported injuries to be submitted which address an issue identified in other community-based sports (Ekegren, Gabbe and Finch 2014). Though the method used in the current study was different to the others reported, where players were called to triage their injury, the current study used an automated text message format to extract as much information about the injury as possible. An average total response rate of 82% (range 70% to 100%) was seen in this study which is similar to other studies that found a weekly response rate ranging from 85% to 90% (Moller, Attermann, Myklebust et al. 2012) and 90% to 98% (Ekegren, Donaldson, Gabbe et al. 2014). The success of this injury reporting method was dependant on the engagement of the players' parents who were central to responding to the text message. This was a necessary requirement due to the players being under age for the research team to contact directly, however in doing so it involved the parents in the injury prevention process for the children. When using this method for injury reporting it is important not to over burden the parents with excessive data requests that may deter their participation. Though it was not formally evaluated, no feedback was received from parents to indicate that the weekly text messages were excessive. Text messaging of injuries has shown to be a feasible option to injury surveillance where there is a lack of personnel and resources in community youth teams however there is a requirement for the research team to administer the delivery, administration and analysis of the data received. Involving players' parents in the injury reporting process in this study, serves as a way of assuming some the responsibility to the parent for children and adolescent sport injury prevention (Emery, Hagel and Morrongiello 2006).

Lessons learnt and future directions

Fidelity of the study was higher when the programme dosage was adhered to by the coach. Considering that coaches felt that the intervention would take away time from their planned session, new evidence suggests that rescheduling part 2 of the FIFA 11+ intervention to the end of the training session improves compliance and reduced the number of severe injuries, enhancing the effectiveness of the 11+ programme (Whalan, Lovell, Steele et al. 2019). Using this approach to scheduling part of the preventive programme at the end of the rugby training session may allow for coaches to complete their planned sessions and schedule in the preventive exercises at the end. Additionally, better support for the coach about injury prevention education needs to be considered for improving adherence by offering workshops to train the coach to implement these routines.

In this small sample of rugby players, the self-reported injury registration method was more favourable in capturing more overall injuries than the coach reported method, which is promising to be used in a larger study. The high SMS response rate suggests that the method is feasible to use in a larger prospective cohort study. Validating the reported injuries with a telephone triage service would be worth considering to improve the accuracy of the injury data. Though this was not evaluated in the current study, other research has demonstrated this method successfully (Moller, Attermann, Myklebust et al. 2012, Ekegren, Gabbe and Finch 2014, Nilstad, Bahr and Andersen 2014).

Strategies to increase recruitment such as a more efficient consent process would be an important consideration in a larger study. There were three teams (n=51 players) that had to be excluded from this study due to non-submission of consent forms. The number of teams (total, n=3) in this pilot study was less than the number of teams involved in a recent pilot study evaluating a strengthening programme for shoulder complaints in handball (Osteras, Sommervold and Skjolberg 2015). Osteras et al. (2015) recruited three teams in each of the experimental (n=3 teams, 53 players) and control groups (n=3 teams, 56 players) from junior league female handball players (mean age 15 years old). Their study acknowledged that the low number of teams was a limitation and proposed future research to complete a power analysis. It is therefore worth considering how to make the recruitment process easier for future studies in community youth rugby union. Players were required to have their parents return a signed consent form to allow their child to participate in the study, but many forms were lost by the players. A potential option to address this issue is to provide parents the option to electronically consent to their child's participation in the study. The information and consent letter sent to parents could include a unique individual code which the parent could include in a SMS to the research team to acknowledge agreement to participate in the study. Prepaid envelops could be provided to allow parents to post their consent back to the research team. A wider youth age range and inclusion of other recruitment sites such as schools and a wider geographical region, could increase the scope for recruiting more teams into a larger study. Another possible strategy to increase recruitment in this population could allow for additional recruitment time. Alongside this, a directed marketing strategy would be advantageous in promoting the study and attracting more clubs to participate.

Conclusion

This pilot study has shown the intervention is feasible to deliver and is acceptable to stakeholders, coaches and players in a community youth rugby setting. Better adherence to the intervention is achieved when coaches prescriptively implement the injury prevention exercise programme. Increasing the understanding about the implementation context is important to enhance real-world impact of this shoulder injury prevention intervention. Self - reported injury using SMS was demonstrated to offer a viable option to injury surveillance in community youth rugby.

Chapter Seven

Effects of a lycra compression sleeve on rugby union players' shoulder function: a pre-experimental study.

Introduction

In English professional rugby players, shoulder dislocation/ instability accounts for 14% -25% of shoulder injuries sustained during rugby matches and training, respectively (Headey, Brooks and Kemp 2007). Shoulder injuries also carry a high overall injury burden, reported as 553 days absent per 1000 hours [95% Confidence interval (CI) = 226, 879] for match injuries in elite English schoolboy rugby players (Barden and Stokes 2018). High velocity collisions in the tackle is a common mechanism for shoulder instability in rugby (Crichton, Jones and Funk 2012) and may result in varying degrees of instability, ranging from sub-clinical to complete fracture dislocation of the glenohumeral joint (Funk 2016). Athletes may present with a combination of clinical patterns of structural and functional instability (based on muscle patterning deficiencies) (Cools, Borms, Castelein et al. 2016) that is dependent on the frequency of instability, mechanism of injury, direction of instability and severity (Kuhn 2010). Interventions with the potential to reduce the risk of shoulder injuries, such as a compression garment identified in chapter two of this thesis, warrant further investigation to better understand the cause-effect relationship of this approach.

The undesirable effects on shoulder function following repetitive impact forces during rugby, such as neuromuscular impairment and instability, may be minimised by using interventions trailed in other populations. Lycra compression sleeves have recently become popular in sport though their use in the management of neurological (Blair, Ballantyne, Horsman et al. 1995, Gracies, Fitzpatrick, Wilson et al. 1997, Gracies, Marosszeky, Renton et al. 2000) and rheumatological (Murphy 1996) conditions and for treating patients with burns (Knox 2003). In patients with upper limb spasticity (n=10), the sleeve minimised muscle contractures by rotating the forearm and producing a continuous low-level stretching force on the limb (Gracies, Fitzpatrick, Wilson et al. 1997). Recently the effectiveness of a lycra compression sleeve intervention was assessed in the management of glenohumeral subluxation in people with stroke (Kumar, Macleod, Mohan et al. 2017). This feasibility mixed-method study included five patients with chronic post-stroke hemiplegia and the primary outcome was assessed by measuring the acromion-greater tuberosity (AGT) distance using real-time ultrasonography (RTUS). It was found that after wearing the compression sleeve for one week there was a reduction of 0.28cm in the AGT distance, suggesting that the sleeve may be beneficial in the management of glenohumeral subluxation. Even though the context of these findings is different, it is plausible to suggest that a lycra compression sleeve may have similar effects in rugby players who have lax shoulders. Additionally, reduced glenohumeral rotation is a recognised risk factor for shoulder injury (Fernandez et al., 2011) and specifically reduced internal rotation (Fernandez, Aravena, Verdugo et al. 2011, McDonough and Funk 2014) in rugby league players, so it is reasonable to hypothesise that the use of joint stabilisers may be beneficial in addressing this ROM deficiency.

In a contact sport like rugby, repeated tackles compromise the shoulder's dynamic control and are a catalyst to altered joint stability (Myers and Lephart 2002). Measurement of humeral head translation has been used as an approach to evaluate shoulder joint laxity (Yeap, McGregor, Humphries et al. 2003, Bahk, Keyurapan, Tasaki et al. 2007, Joseph, Hussain, Pirunsan et al. 2014), though a review of these assessment methods (see chapter two) highlights the need for a novel method to evaluate humeral head translation in rugby players. The posteroanterior direction of force imposed to the shoulder in previous studies (Court-Payen, Krarup, Skoldbye et al. 1995, Krarup, Court-Payen, Skjoldbye et al. 1999, Joseph, Hussain, Pirunsan et al. 2014, Henderson, Worst, Decarreau et al. 2016) does not resemble the actual forces incurred during the tackle or other mechanisms of shoulder injury (Crichton, Jones and Funk 2012). Trialling a new method to evaluate humeral head translation may be advantageous to detect the effects of an intervention such as a lycra compression sleeve on shoulder function.

Shoulder joint laxity and abnormal neuromuscular control are associated with the continuum of pathologies described in the Stanmore classification of shoulder instability (Lewis, Kitamura and Bayley 2004, Herrington, Horsley, Whitaker et al. 2008, Jaggi, Noorani, Malone et al. 2012, Morgan and Herrington 2014, Faria, Campos and Jorge 2017). The Stanmore classification is useful to classify patients into three polar groups but it is apparent that there is a continuum between these categories, recognising that more than one pathology can co-exist, leading to sub-groups being proposed (Lewis, Kitamura and Bayley 2004). For example, muscle patterning disorders have been demonstrated in patients who have sustained a traumatic shoulder dislocation with structural damage (Jaggi and Alexander 2017). Bearing this in mind, and in addition to measuring shoulder laxity, assessing glenohumeral rotation, rotator cuff muscle strength and trunk stability are considered valuable in the continuum of shoulder instability (Jaggi, Noorani, Malone et al. 2012). In clinical practice it is necessary to specifically evaluate the integrity of the shoulder joint, but it is also important to assess the shoulder functionally. The shoulder does not function in isolation and can be influenced from structures above and below the joint. Evidence presented regarding the association between grip strength and rotator cuff muscle function warrants the inclusion of grip strength in the evaluation of shoulder function (Goto, Tsuruta , Mura et al. 2005, Alizadehkhaiyat, Fisher, Kemp et al. 2011, Horsley, Herrington, Hoyle et al. 2016). Addressing these outcomes is useful in managing people with shoulder instability and provides a marker to evaluate whether an intervention has been effective.

Injury prevention

Support sleeve use was prospectively investigated in a cohort of 304 rugby players as part of the Rugby Injury and Performance Project (RIPP) in New Zealand (Marshall, Loomis, Waller et al. 2005). Ankle, knee or upper extremity support sleeves tended to be protective over the course of a competitive club season, with a decreased risk of players sustaining a strain or sprain (Rate Ratio [RR] =0.58, 95%CI: 0.26 -1.27). An inherent limitation of this study was that players self-reported their injuries, raising concerns about misclassification, though players were telephoned weekly to minimise the risk of recall bias.

Considering that the commonly cited reasons for rugby players voluntarily using protective equipment over the course of a season was that it prevented injury (70.2%) and because of past injury (65.5%) (n=252) (Marshall, Waller, Loomis et al. 2001), there is an impetus for researchers to fully evaluate the potential effects of equipment to determine their prophylactic and rehabilitative benefits. In addition to evaluating the physiological outcome measures relating to shoulder function, a broader comprehension of the effects of protective equipment can be gained by subjectively evaluating the players' perceptions of their perceived benefits of using the equipment. The patient's perception of their shoulder function is considered an important outcome measure that provides an improved understanding of the overall effects of the equipment (Romeo, Mazzocca, Hang et al. 2004). Therefore, a simple patient reported outcome measure for the shoulder would be a beneficial tool to use to further evaluate the effect of the compression sleeve.

Aim

The aim of this study was to determine if wearing a lycra compression sleeve for one week will confer structural or functional benefits to rugby union players' shoulders when tested without the sleeve on. Specifically this will be evaluated against the following outcome measures; glenohumeral joint laxity and shoulder instability [inferior glenohumeral joint laxity (distance between acromion and greater tuberosity of humerus) and anterior translation of the humeral head (distance between the coracoid process and the most superior aspect of the humeral head)] measured using RTUS, shoulder range of movement (internal and lateral rotation), lateral shoulder rotator strength and grip strength and the Upper Quarter Y Balance Test (functional stability test). The feasibility of using the lycra compression sleeve was a secondary objective, determined by identifying the players' adherence to using the lycra compression sleeve over a one-week intervention period.

Methods and methodology

Study design

Preliminary testing was carried out with six healthy volunteers to refine the development of the RTUS outcome measure. The volunteers were male undergraduate students that participated in football and rugby for their university. Following this pilot testing, a repeated measures study was carried out over one week of the rugby season between January - March 2017. Testing was conducted with rugby players from the respective universities in a sport hall at the Centre for Sport at the University of the West of England (pre-test: 27th and 28th February 2017, post-test: 6th and 7th March 2017) and in the Applied Biomechanics Suite at the University of Bath (pre-test: 2nd and 3rd March 2017, post-test: 9th and 10th March 2017).

Participant recruitment

Male rugby union players from the University of the West of England and the University of Bath, between the ages of 17 and 21 years, were invited to participate in the study. Contact was made first with the head coach for both teams via email, telephone calls and in person to establish if their teams would be available and interested in participating in the study. Detailed information and paper copies of the consent forms were then sent out to the players (Appendix E). Players with current or recent (past three months) shoulder injury/pain or a skin allergy to lycra were excluded from the study. Asymptomatic players were included in this feasibility study to allow the testing method to be evaluated before it is used with players with shoulder injury/pain. The Faculty Research Ethics Committee at the University of the West of England approved this study.

Tester training and testing arrangements

The selected outcome measures were tests that are used to assess the common characteristics exhibited by people with shoulder instability as described in the Stanmore classification of shoulder instability (Lewis, Kitamura and Bayley 2004). The testers remained the same for each test throughout the data collection period. The testers were five undergraduate students in the final year of a three-year honours degree in sport rehabilitation, and one chartered physiotherapist with 15 years of experience in the assessment and management of musculoskeletal conditions. All undergraduate students had academic and supervised clinical experience (minimum of 400 hours) in assessing musculoskeletal conditions. In addition, they were specifically trained on the tests they administered in this study. They underwent one day of training which was instructed by the lead researcher (VS) and, in addition, an instruction pack was available for their reference. A small sample of undergraduate students volunteered to participate in practice sessions of all tests, which allowed fine-tuning of the testing procedures and determination of testing duration. Pilot testing of a novel RTUS method was also carried out during this preparatory phase and is subsequently described in detail.

Players were able to book testing in groups of up to five, using an online booking system. It took each player 60 minutes to complete all tests. When players arrived at the venue, they were given the study information form to re-read and were verbally reminded about the purpose of the study. Participant demographics, anthropometric measures and the Stanmore Percentage of Normal Shoulder Assessment (SPONSA) (Noorani, Malone, Jaggi et al. 2012) were completed first. Players were then randomly allocated to whichever testing station was available so that the tests were completed in the allotted time. Pre and post testing were conducted bilaterally without the compression sleeve on. This allowed the players' non-dominant arm to serve as their own control.

Real time ultrasonography measurement

Two measurements were taken using RTUS. One method followed previously described procedures using the acromion-greater tuberosity as a landmark (Park, Kim, Sohn et al. 2007, Cholewinski, Kusz, Cielinski et al. 2008, Kumar, Bradley and Swinkels 2010) and is outlined below. The second method was a novel procedure developed for this study to impose anterior translation of the humeral head by scrutinising the applied functional anatomy of the shoulder. The superior pectoralis major muscle and the inferior latissimus dorsi muscle have significant potential to destabilise the glenohumeral joint by imparting superior and inferior shear to the glenohumeral joint, respectively (Ackland et al. 2009). A tonic spasm of the pectoralis major muscle also has the ability to dislocate the glenohumeral joint in extreme cases, such as in patients with hypermobility syndrome (Sinha, Higginson and Vickers 1999). Over activity of the pectoralis major muscle was also identified in 77 of 95 (81%) of shoulders with anterior instability (Jaggi, Noorani, Malone et al. 2012). Electromyography research has investigated the muscle activation pattern during a rugby tackle and suggest that an altered muscle recruitment pattern including premature onset of the pectoralis major muscle can contribute to inappropriately positioning the humeral head

(Herrington and Horsley 2009). Therefore, the line of action of the pectoralis major muscle and its potential destabilising role of the humeral head were considered to impart a superior shear force during an isometric contraction of the pectoralis major muscle during flexion of the shoulder in the sagittal plane.

A portable diagnostic ultrasound, (TITAN model, M Mode, Depth 3.9, L38/10-5 MHz broadband 38 mm linear array transducer, Sonosite Limited, Hitchin, UK) was used for scanning the shoulder and recording the distance between the anatomical landmarks. Testing and calibration of the equipment in accordance with the manufacturer's guidelines was carried out prior to commencement of data collection. The ultrasound unit was operated by VS, who completed a training protocol consisting of one day of training with a clinician with experience in scanning and recording the AGT distance and supervised training from a consultant radiologist using this method.

Each player sat upright with his shoulders against the back of a chair, topless with pillows on his lap. For the static AGT measurement (old method), the players rested both their forearms on the pillow with their elbow unsupported ensuring the shoulder girdle was not elevated. The forearm was in pronation with the elbow flexed at 90º and the shoulder in neutral. The lateral border of the acromion was then palpated to allow for the placement of the ultrasound transducer head along the longitudinal axis of the humerus. The two bony landmarks were identified on the frozen image and the AGT distance was measured using the scanner's inbuilt callipers. The distance between the lateral edge of the acromion process of the scapula and the nearest margin of the greater tuberosity of the humerus defined the AGT distance (see figure 13).

Figure 13. Real-time ultrasound image of AGT distance

For the dynamic anterior humeral head translation measurement (novel method), a bubble clinical goniometer was secured to the player's distal pronated forearm so that the tested arm could be raised to 45º shoulder flexion with his elbow fully extended. Once this position was reached, pillows were placed on the player's lap so that his arm remained in this position. The player was then given a handheld dynamometer (MicroFET, Hoggan Health Industries, Draper, UT, USA) which had an adjustable strap attached to it and was secured to the leg of the chair so that the player's arm remained in 45º shoulder flexion. The assessor then imaged the shoulder anteriorly, visualising the anatomical structures required to measure the horizontal distance between the most superior aspect of the coracoid process and the most superior aspect of the humeral head with the arm held relaxed at 45º shoulder flexion. A mark was made on the player's skin to indicate the placement of the probe during the isometric contraction test. After a measurement was taken in the relaxed state, the diagnostic ultrasound probe was kept in position and the handheld dynamometer was switched on and the player was instructed to pull the fixed handheld dynamometer maximally while trying to keep his arm extended at the elbow and in the same plane. During this contracted state, the assessor measured the horizontal distance with five seconds of the players' isometric contraction. The force measurement on the handheld dynamometer and the horizontal distance were recorded. This novel method was explored but usable images were not obtained, so could not be employed to address the aims of this study.

Anthropometric testing

Players were barefoot, wearing shorts and t-shirts for all anthropometric measurements. Standing height was measured to the nearest 0.1 cm using a free-standing stadiometer (Invicta Plastics Limited, Leicester England). Players' body mass was assessed to the nearest 0.1 kilogram using a SECA mechanical scale.

Glenohumeral internal and external range of motion

Active and passive shoulder range of motion was measured by two assessors and was done on the same portable treatment plinth for all players. A clinical bubble goniometer with a rotating dial marked in 1º increments (MIE Medical Research, Leeds UK) and a plastic goniometer marked in 1º increments with two adjustable overlapping arms were used. The plastic goniometer was used to position the players' arm in 90º glenohumeral abduction and the bubble goniometer was attached to the player's distal forearm in line with the styloid process of the ulna on the anterior or posterior aspect, depending on the direction of movement. Active and passive range of motion were evaluated bilaterally in supine with 90º glenohumeral abduction and 90º elbow flexion. One of the assessors took the reading while the other assessor palpated the players' corocoid process and anterior humeral head with their thumb and index finger, respectively, to detect scapula compensation during the movement (Cools, De Wilde, Van Tongel et al. 2014).

The intra-rater reliability of a bubble goniometer has been previously established for measuring shoulder range of motion for internal rotation (ICC=0.987) and external rotation (ICC=0.970), (Kolber, Fuller, Marshall et al. 2012). Inter-rater reliability for internal and external rotation demonstrated ICCs of 0.62 and 0.72, respectively, in normal shoulders (Muir, Corea and Beaupre 2010). As rugby players often tackle with a flexed hip position, resulting in shoulder external rotation with the torso in a prone position, shoulder external rotation was assessed in this position. Active range of internal and external rotation was also measured in the prone position, as it was deemed relevant and specific to the athlete.

Orthopaedic evaluation for shoulder instability

The load and shift (LAS) test was done with the player seated and his arm is placed in 20º abduction and 20º of forward flexion, in neutral rotation. The assessor stood behind the player, with one hand stabilising the scapula while the other hand grasped the humeral head. Both anterior and posterior stresses were applied and the amount of translation noted with the magnitude of the translation graded 0 – III, with grade 0 (no or minimal translation), grade I (<1cm translation), grade II (1.0 to 2.0 cm) or grade III (>2.0cm) (Silliman and Hawkins 1993). The interrater reliability of the load and shift test was evaluated on the non-dominant arm of twenty-nine asymptomatic participants (19 recreational weight training history and 10 sedentary, mean ±SD age 24.7±4.9 years) (Kolber and Corrao 2010). The test possesses good interrater reliability (ICC=0.80, 95% CI 0.61 to 0.90) in asymptomatic populations.

Muscle strength tests

Hand grip strength was measured using a hand-held dynamometer. The player stood upright against a wall with his arm in three different testing positions: neutral, 90º abduction and 90º abduction with 90º external rotation as described by Horsley et al. (2016). The player's wrist was kept in neutral and his elbow at 90º flexion in all positions while completing a five second maximal contraction. The average of two attempts was recorded and players were allowed one minute of rest time between repetitions.

Shoulder external rotation was assessed using a hand-held dynamometer (Lafayette Manual Muscle Tester Model 01163, Lafayette Instrument Company, IN, USA) in the same positions as those for the grip strength test (Horsley, Herrington, Hoyle et al. 2016). The wall was used for stability and to counter the resistance when testing in neutral and 90º abduction with 90º external rotation. When testing in the 90º abduction position, the height of the player's shoulder was positioned using an adjustable strap with the hand-held dynamometer placed in between the strap and dorsal aspect of the player's hand to provide resistance to the maximal contraction in the upward direction. Players had two attempts (average of the two was recorded) at completing a five second maximal contraction and were allowed one minute of rest time between repetitions.

Functional tests

The Upper Quarter Y – Balance Test (UQYBT) challenges the athlete's limits of stability, focusing on upper limb balance, proprioception and mobility of the spine and scapula while being able to produce unilateral measures that may be useful in identifying asymmetries (Taylor, Wright, Smoliga et al. 2016). The UQYBT is suggested to measure upper limb strength, stability and mobility (Gorman, Butler, Plisky et al. 2012, Westrick 2012). The test was performed using the Y Balance Test Kit (Move2Perform, Evansville, IN, USA). Upper limb length was measured using a fibreglass meter from the spinous process of C7 to the tip of the longest digit with the shoulder abducted to 90º, with the elbow extended and wrist and hand in neutral. The player began in the push up position with his testing hand on the stance platform of the Y – Balance kit. The reach hand was on top of the medial reach indicator and his feet were no more than twelve inches apart (Gorman, Butler, Plisky et al. 2012, Westrick 2012). While maintaining the push up position, the player performed the reach with his reaching hand in three directions (medial, superolateral and inferolateral) named in relation to his stance hand. Discarded attempts were based on criteria set out by Gorman et al. (2012). Players were allowed three attempts and the average score was used in the analysis. The sum of the three reach directions was calculated for the total excursion score, which was normalised for limb length by dividing this score by three times the upper limb length (Westrick 2012). Test re-test reliability for this test has been shown to range from 0.80 – 0.99 (ICC) and inter-rater reliability has been established as 1.00 (ICC) for men and women (Gorman, Butler, Plisky et al. 2012, Westrick 2012).

Stanmore Percentage of Normal Shoulder Assessment

This patient-reported outcome measure (PROM) uses one question to assess pain, range of movement, strength, stability and function of the shoulder. The script for the assessor was laminated and read aloud to the players, and a verbal response was obtained (see appendix F for full text):

> *"Overall where would you rate your shoulder between 0 and 100 percent, at this present time?"*

The Stanmore Percentage of Normal Shoulder Assessment (SPONSA) has excellent construct validity, demonstrating a 0.79 and 0.78 correlation with the Oxford Shoulder Score (OSS) and the Constant Score, respectively (Noorani, Malone, Jaggi et al. 2012). In their study, which included 61 patients recruited at the preoperative assessment clinic who were awaiting to undergo a surgical shoulder intervention, the sensitivity to change (effect size 0.72) has been found to be comparable to the Oxford Shoulder Score (effect size 0.65). The SPONSA is quick to administer, reliable, demonstrated construct validity and is sensitive to change, making it a suitable assessment in this study. Permission to use the SPONSA was agreed by the researchers who developed the questionnaire.

Adherence and comfort of using sleeve

Following baseline testing, all players were fitted with a Sensory Dynamic Orthosis (SDO®) lycra compression sleeve (manufactured and supplied by Jobskin® Nottingham, United Kingdom) on their dominant arm according to the manufacturers' instructions. The compression sleeve used in this study covered the participant's dominant arm from the wrist up to midway of the humerus. They were asked to wear it on their dominant arm for one week, seven hours per day. Players were asked to complete a diary recording when and how long the compression sleeve was worn during the study. Testing was conducted bilaterally and without the sleeve on, which allowed players to serve as their own controls. When the players returned to be re-tested, they also completed a brief questionnaire that evaluated the comfort and ease of wear of the lycra compression sleeve. Level of comfort and ease of wear were evaluated subjectively on the basis of:

- Fit on the arm (select one): excellent (fits the arm perfectly), good, requires improvement, inadequate (too wide or too tight).
- Fit of the top sleeve band (select one): excellent (does not constrict), good, requires improvement, inadequate (cuts into skin).

- Ability to stay in place (select one): excellent (does not slide), good, requires improvement, inadequate (slides immediately)

- Player reported irritation from wearing the compression sleeve, if experienced, players selected one or more of the following (select one or more): redness, itching, discomfort related to heat and tightness of the sleeve and or cuff cutting into the skin.

Analysis

To investigate the difference in the pre- and post-intervention outcome measures for the dominant shoulder, paired samples t-tests were used. The data were checked for normality using the Shapiro-Wilk test and a box-plot was graphically interpreted for outliers. Normally distributed data were analysed using a paired samples t-test and data with extreme outliers were analysed using Wilcoxon signed-rank test at the 95% confidence interval. Outcomes with a significant pretest-posttest difference were similarly analysed to determine if there was a significant difference between the dominant and non-dominant arms. All analyses were conducted using IBM SPSS Statistics Version 25 software.

Results

Participant characteristics

Seventeen players were tested at baseline, but six players did not return for the post-test. Of these six, one player sustained a shoulder injury which excluded him from the study and the remaining five did not provide a reason for withdrawing. There were 11 players included in the final analysis with the following characteristics: (mean± standard deviation) age of 20 years ±1, height 1.82 meters ±6cm and weight 90 kilograms ±14kgs. The group consisted of four forwards and seven backs, with seven players having more than 10 years rugby playing experience (sample range: 4 years to >10 years). Ten of the 11 players were right-hand dominant.

Normality of data

There were outliers of more than 1.5 box-lengths for active range of shoulder internal rotation in prone, dominant arm grip strength at 90º/ 90º (abduction / external rotation), and external rotation muscle strength (duration to peak muscle force generation) at 90º / 90º (abduction/ external rotation). The box plots were graphically interpreted and the data was kept in the analysis where there were no extreme outliers.

Real Time Ultrasound

The static measurement of the AGT distance produced acceptable quality images and results are presented in Table 26. There was no significant difference in the real time ultrasound measurements for shoulder acromion-greater tuberosity (AGT) distance after using the sleeve, [t = -0.562, p=0,587]. The mean pre-test AGT distance was 1.94 (+/- 0.53) centimetres (cm) and 1.81 (+/-0.37) cm for the non-dominant and dominant arm, respectively. There was a 3% (range -28% to 29%) reduction in the AGT distance in the dominant arm compared to a 1% (range -29% to 25%) reduction in the non-dominant arm following the intervention.

	Minimum (cm)	Maximum (cm)	Mean (cm)	Std. Deviation
AGT dominant pre-test	1.14	2.62	1.81	0.37
AGT dominant post-test	1.37	2.28	1.75	0.24
AGT non-dominant pre-test	1.21	2.71	1.94	0.53
AGT non-dominant post-test	1.34	2.47	1.93	0.36

Table 26: Descriptive data for Acromioclavicular-greater tuberosity (AGT) distance

Glenohumeral joint range of motion

There was a statistically significant increase in players' active range of motion for shoulder external rotation after using the lycra sleeve [t = 3.18, p=0.010]. There was no significant difference between the mean values for the dominant and non-dominant arms at baseline. A 10% (range -5% to 29%) increase in active range of motion for shoulder external rotation was found for the dominant arm and a 3% (range -8% to 31%) increase for the non-dominant arm. The pretest-posttest results for passive internal rotation was significantly different after using the sleeve [t=3.00, p=0.008]. There was an 18% increase in passive range of motion shoulder internal rotation after using the sleeve compared to an 8% increase in the control arm (Table 27).

		Minimum	Maximum	Mean	Std. Deviation
Active range of motion (AROM)					
Supine					
External rotation non-dominant arm	pre-test	53.50	92.50	75.00	11.80
	post-test	66.50	91.00	77.32	7.42
Percent change (mean)				3%	
External rotation dominant arm	Pre-test	68.50	94.00	80.27	8.48
	Post-test	72.50	109.00	87.91	11.32
Percent change* (mean)				10%	
Internal rotation non-dominant arm	Pre-test	32.00	67.50	53.36	9.59
	Post-test	45.00	77.00	59.36	10.62
Percent change (mean)				11%	
Internal rotation dominant arm	Pre-test	32.50	72.50	49.77	12.95
	Post-test	45.50	6.50	54.00	6.79
Percent change (mean)				8%	
Prone					
Internal rotation non-dominant arm	Pre-test	31.00	85.00	54.41	16.11
	Post-test	34.50	70.00	49.91	9.40
Percent change (mean)				-8%	
Internal rotation dominant arm	Pre-test	32.50	85.00	47.77	14.96
	Post-test	39.50	62.50	48.95	6.65
Percent change (mean)				2%	
External rotation non-dominant arm	Pre-test	67.00	90.5	78.96	6.71
	Post-test	65.00	96	83.41	9.81
Percent change (mean)				6%	
External rotation dominant arm	Pre-test	64.50	102.5	84.91	11.86
	Post-test	69.50	106.5	86.00	12.82
Percent change (mean)				1%	
Passive range of motion (PROM) Supine					
External rotation non-dominant arm	Pre-test	83.00	110.00	93.86	7.90
	Post-test	89.50	106.00	95.59	4.68
Percent change (mean)				2%	
External rotation dominant arm	Pre-test	84.50	110.00	98.64	9.66
	Post-test	91.00	118.50	102.8	9.00
Percent change (mean)				4%	
Internal rotation non-dominant arm	Pre-test	41.50	93.00	72.36	12.92
	Post-test	63.50	93.50	77.86	9.87
Percent change (mean)				8%	
Internal rotation dominant arm	Pre-test	37.50	80.00	62.45	14.03
	Post-test	59.50	86.00	73.50	9.35
Percent change* (mean)				18%	

*Significant difference

Table 27: Mean and percent change for range of motion tests

Orthopaedic evaluation of shoulder laxity: load and shift test

The mean shoulder laxity scores did not change after using the sleeve (mean laxity grade remained 1 pretest-posttest), though individual players demonstrated alterations. The majority of players' scores for their dominant arm did not change except for one player who's score reduced indicating a reduction in laxity. There was a mean change in laxity scores for the control arm for all players (mean laxity grade=1 pretest, increased to grade 2 posttest) with three players increasing their posttest laxity score on their non-dominant arm.

Muscular strength and Upper Quarter Y Balance Test

The mean differences in grip strength after using the sleeve at 90º abduction and at 90º abduction 90º external rotation was -1% and -10%, respectively (Table 28). A mean difference of 5% in grip strength was found on post-test for the non-dominant arm at 90º abduction.

	Grip strength					
	0º		90º Abduction		90º/90º	
	Non-dominant	Dominant	Non-dominant	Dominant	Non-dominant	Dominant
Pre-test	49.61	51.47	43.84	49.21	46.75	49.33
Post-test	49.88	51.55	46.13	48.81	45.79	44.45
Percentage change (mean)	1%	0%	5%	-1%	-2%	-10%
Paired t-test						
Mean		1.94		4.98		-2.30
Std. Deviation		4.70		11.05		8.40
95% CI						
Lower		-1.22		-2.44		-7.95
Upper		5.09		12.40		3.34
t		1.37		1.50		-0.910
Sig (2-tailed)		0.202		0.166		0.384

Table 28: Mean values, percent change and paired t-test (dominant arm) for grip strength

There was a mean increase in shoulder external rotation strength for dominant and non-dominant arms at 90º abduction of 57% [t=4.22, p=0.002] and 58% [t=3.83, p=0.003] respectively, as well as in the 90º abduction 90º external rotation position [62% (t=4.32, p=0.002) and 65% (t=3.72, p=0.004)] (Table 29). Reductions of - 18% and -14% were seen in the time taken to reach the peak force for shoulder external rotation strength on the dominant and non-dominant side at 90º abduction. There was no significant difference in the UQYBT after using the sleeve [$t = 0.393$, $p=0.703$].

		Minimum – Maximum	Mean (Std. Deviation)	Mean (Std. Deviation)	Paired t-test (95% CI)		t	sig
					lower	**upper**		
90º External rotation strength non-dominant arm	pre-test	17.55 - 58.80	32.27 (13.58)					
	post-test	35.70 - 73.70	51.13 (12.81)					
Percent change* (mean)			58%					
90º External rotation strength peak non-dominant arm (seconds)	pre-test	1.96 - 5.00	3.92 (0.94)					
	post-test	1.83 - 4.38	3.38 (0.63)					
Percent change (mean)			-14%					
90º External rotation strength dominant arm	pre-test	16.90 - 57.45	32.19 (13.36)					
	post-test	33.15 - 68.60	50.63 (10.70)	18.44 (14.48)	8.71	28.16	4.22	0.002*
Percent change* (mean)			57%					
90º External rotation strength peak dominant arm	pre-test	3.12 - 4.67	3.87 (0.51)					
	post-test	1.63 - 4.47	3.16 (0.96)	-0.71 (1.26)	-1.56	0.13	-1.88	0.090
Percent change (mean)			-18%					
90º Abduction 90º External rotation strength non-dominant arm	pre-test	4.60 - 17.85	9.19 (4.09)					
	post-test	9.95 - 24.45	15.14 (4.45)					
Percent change* (mean)			65%					
90º Abduction 90º External rotation strength peak non-dominant arm	pre-test	2.50 - 4.34	3.39(0.69)					
	post-test	1.76 - 4.13	3.08(0.82)					
Percent change (mean)			-9%					
90º Abduction 90º External rotation strength dominant arm	pre-test	4.55 - 13.45	8.88 (3.03)	5.53 (4.25)	2.68	8.38	4.318	0.002*
	post-test	10.20 - 20.75	14.41 (3.81)					
Percent change* (mean)			62%					
90º Abduction 90º External rotation strength peak dominant arm	pre-test	2.51 - 4.54	3.44 (0.64)	Nonparametric Wilcoxon signed rank			38.00	0.657
	post-test	1.62 - 6.06	3.26 (1.13)					
Percent change (mean)			-5%					

Table 29: Mean values, percent change and paired t-test (dominant arm) for shoulder external rotation strength.

*Significant difference

Stanmore Percentage of Normal Shoulder Assessment (SPONSA)

There was a no change in the SPONSA after using the sleeve (mean±SD, pretest SPONSA score 83±12.25, posttest 83±11.24), though a non-significant 2% increase was seen in the non-dominant arm (pretest mean 78±11.18, posttest mean 80±11.06) [t = -0.18, p=0.86].

Comfort and fit of sleeve

The majority of players' (nine out of 11) ranked their level of satisfaction with the fit of the sleeve as 'excellent'; however, seven players indicated that the fit of the proximal part of the sleeve 'required improvement'. A similar number of players indicated that the sleeve did not stay in place. The most common irritation from the sleeve was itching, followed by redness, discomfort and tightness. On average the sleeve was worn for 44.4 hours (range 31 to 70 hours) over seven days. This equates to participants wearing the sleeve for 90% of the potential 49 hours during the study which shows a high level of adherence to using the compression sleeve.

Discussion

This study evaluated the effects of a lycra compression garment on shoulder function in rugby players. It demonstrated that wearing a lycra compression sleeve for seven days increased active shoulder external rotation range of motion by 10% [t = 3.18, p=0.010] and passive shoulder internal rotation range of motion by 18% [t=3.00, p=0.008] in young, male rugby players. Previous reports of shoulder range of motion deficits in rugby players give reason to suggest that, with further investigation, the sleeve may be beneficial for players presenting with this limitation. These initial findings show that the sleeve may prevent an increase in the acromion-greater tuberosity distance and glenohumeral laxity when assessed clinically. Considering the burden of shoulder dislocations in rugby, further evaluation of the use of the sleeve is an advantageous countermeasure to pursue.

This study trailed a new method to evaluate anterior humeral head translation during maximal isometric muscle contraction (shoulder flexion) using real time ultrasound and a hand-held dynamometer. Poor image quality and the inconsistency in locating the bony landmarks in some participants was experienced and has been previously reported (Yeap, McGregor, Humphries et al. 2003, Joseph, Hussain, Pirunsan et al. 2014, Rathi, Taylor, Gee et al. 2016). Apparent larger shoulder muscle bulk, dynamic muscle tension of the global muscles (anterior deltoid and pectoralis major muscles) and the contribution from other muscles activity (peri-scapular muscles and rotator cuff muscles) also contributed to the unclear image quality. Due to these visualisation issues and the effect of the dynamic muscle activity around the shoulder, this method could not be reliably used to anterior humeral head translation.

Using a static measure, there was a small reduction in mean AGT distance of 0.06 cm (-3%) after using the lycra compression sleeve compared to not wearing the sleeve [0.01cm (-1%)], though this was not statistically significant. In a mechanistic study in healthy young people (n=31, mean ±SD age 25 ± 10 years), a significant reduction in AGT distance (0.12 cm, 95% CI 0.07-0.16 cm, t=5.112, p=0.003) was found immediately after application of a lycra compression sleeve (Kumar, Desai and Elliot 2019). Our smaller sample size (n=11) may account for the wider confidence interval (-0.28 to 0.17) compared to Kumar et al. (2019). The greater reduction in AGT distance reported by Kumar et al. (2019) may have been influenced by taking the measurements while still wearing the sleeve, which was not the case in our study. It has also been suggested that the application of the sleeve may cause an approximation of the humerus into the glenohumeral joint and externally rotate the shoulder joint (Kumar, Desai and Elliot 2019). This effect was also shown in people with chronic stroke (n=5) using a sleeve, concluding that the AGT distance on day one with 'sleeve off' compared to day 8 with 'sleeve on' was reduced by 0.27 cm (95% CI, 0.13-0.4 cm, t=5.55, p=0.005) (Kumar 2019). Due to the contact nature of rugby it would not be practical to wear the sleeve while playing as it could easily be pulled out of place. Therefore, evaluating AGT distance with the sleeve on would not be transferable to its use in the sport context. To understand the practical benefits of using the sleeve, testing players without the sleeve on after having worn the sleeve for a period of time is applicable when considering the residual effects the sleeve may have following its use as part of a prehabilitation or rehabilitation plan.

A study conducted on young healthy people (n=16, mean ±SD age 28 ± 11 years) evaluating the effects of different arm positions found a change of ≥0.10 cm [standard error measurement (SEM)] in the AGT distance would be required to be considered a real change in measurement across different arm positions (Kumar, Bourke, Flanders et al. 2014). Even though the findings in our study were not statistically significant, there were 7 out of 11 players (64%) who had a reduction of ≥0.12 cm after using the lycra compression sleeve compared to 5 out of 11 (45%) on the non-dominant arm. In contrast, the AGT distance increased for three out of 11 players (27%) in our study after using the sleeve compared to 6 out of 11 players (55%) without the sleeve on their non-dominant arm. The increase in AGT distance may have been a result of impact during rugby training and match play during the study period, suggesting that the sleeve protected some players from an increase in their AGT distance. These preliminary findings suggest an inter-individual variation which may have practical implications for players that wear the sleeve during the post-match or training period to enhance the shoulder's recovery following repeated collisions in rugby. The sleeve may prevent an increase in the acromion-greater tuberosity distance and glenohumeral laxity when assessed clinically. Considering that repetitive impacts to the shoulder may contribute to the development of laxity, there is further support to further evaluate the potential benefits of the sleeve.

In a healthy population, rugby conditioning can contribute to passive shoulder muscle tension which may have been modulated after using the sleeve resulting in the increased shoulder motion. Reduced shoulder internal rotation range may predispose overhead athletes to injury in a number of sports (Keller, De Giacomo, Neumann et al. 2018) and appeared to predict future injury in a prospective cohort study on a group of professional rugby league players (n=20, mean ± SD age 19.6±1.77 years) (McDonough and Funk 2014). These rotator cuff muscle imbalances are shown to be associated with a mal-positioning of the glenohumeral head and leading to SLAP lesions in rugby players. Rugby players with reduced shoulder internal rotation range were more likely to injure their shoulder during the season (left p=0.02 and right p=0.02) compared to non-injured players. Increasing shoulder range of motion by using the sleeve might be beneficial in addressing the reported deficits in rugby players shoulder range of motion (Fernandez, Aravena, Verdugo et al. 2011, Horsley, Pearson, Green et al. 2012, Bolton, Moss, Sparks et al. 2013, McDonough and Funk 2014).

Using the sleeve for seven days resulted in a 7.64º (mean) (10%, t=3.18, p=0.01) increase in active range of motion for supine shoulder external rotation and an 11.05º (mean) (18%, t=3.00, p=0.008) increase in passive range of motion for shoulder internal rotation. A slightly lower increase in passive shoulder range of motion (mean increase in range 4.1º± 13º per shoulder movement, p<0.01) was found in a crossover design study after three hours of using the sleeve on 16 participants with hemiplegia (mean age 65 years old) (Gracies, Marosszeky, Renton et al. 2000). The mechanism for these changes is unknown and the authors proposed that it may be attributed to cutaneous input from wearing the sleeve influencing the regional gate control effect at the spinal level. An understanding about the potential mechanisms by which the sleeve may influence shoulder function is helpful to propose its role in addressing risk factors associated with shoulder injuries in rugby.

Anterior glenohumeral translation measured by the load and shift test was allocated a grade of 'I' (<1cm translation), on the four-level grading scale (Silliman and Hawkins 1993) after using the sleeve (-8%) compared to an increase of one level without the sleeve on the non-dominant arm (baseline grade I to post-test grade II (1.0 to 2.0 cm, mean increase of 13%). This was the first study to evaluate the effects of the sleeve on this shoulder instability outcome measure, limiting comparison of the results. Fewer players' (two out of 11, 18%) dominant arms were classified as grade II compared to 4 out of 11 (36%) of their non-dominant arms during the pre-test shoulder instability test. The number of players with grade II laxity increased to six out of 11 (55%) for the non-dominant arm while this reduced for the sleeve arm (one out of 11) during the post-test. These findings suggest that the sleeve protected more players from increasing anterior glenohumeral laxity when evaluated using the load and shift test. It is unknown what exactly contributed to this increase in laxity as the players' training load during the study was not recorded. Yet, this increase in shoulder laxity on the non-dominant side aligns with evidence from rugby injury studies. Professional rugby players (n=166, mean age 18 years) dislocated their non-dominant shoulders (57%) more than their dominant shoulder (Sundaram, Bokor and Davidson 2011). Moreover, a recent retrospective study about shoulder dislocations showed a higher number of rugby players (17 out of 28) injured their non-dominant shoulders than dominant shoulders (Lim, Yap and Campbell 2018). At the design stage of our study the dominant arm was chosen for the sleeve considering that higher peak impact force is reported in the dominant side during the tackle (Usman, McIntosh and Frechede 2011, Seminati, Cazzola, Preatoni et al. 2017). Based on the risk of sustaining a shoulder injury in rugby players' non-dominant shoulders, there is no reason why a player could not incorporate the compression sleeves bilaterally to offer a potential benefit to prevent players sustaining a shoulder injury.

There was a non-significant reduction (10%) in the post-test grip strength at 90º abduction and 90º external rotation after using the sleeve. The sleeve has been designed to supinate the forearm, producing a continuous low-level stretching force on the pronator muscles of the wrist (Gracies, Fitzpatrick, Wilson et al. 1997). Taking into account that acute static stretching of the finger flexors has been shown to negatively impact the rate of force generation of handgrip strength (n=30 resistance trained participants, mean ±SD age men 27±10 years, females 25±6 years) by 4.4% (p=0.001) (Jelmini, Cornwell, Khodiguian et al. 2018), it may explain the reason for the reduction in grip strength found in our study. A systematic review synthesising the effects of acute static stretching (30-45 seconds) on maximal muscle power found significant reductions in hand grip strength (7.8%) with longer duration stretches in other muscles causing moderate performance reductions (Kay and Blazevich 2012). In the absence of further evidence on the effects of prolonged stretching on grip strength, the implications of these findings require further investigation.

There is some indication that the post-test increases in both arms for the testing positions of shoulder external rotation strength was the result of a "learning effect". We know from other studies that better scores on the shoulder external rotation isokinetic strength re-test have been reported in 21 healthy recreational athletes (mean ± SD age men 27.5±2.76 years, women 25.17±2.37 years) while no such effects were observed for shoulder internal rotation isokinetic strength (Hadzic, Ursej, Kalc et al. 2012). Other research has shown that re-testing chronic low back pain patients after 5-10 days (Keller, Hellesnes and Brox 2001) resulted in significant improvement in muscle power compared to re-testing 2-3 days after baseline measurements. This possible learning effect could be diminished by repeating the baseline measurement after one or two days and using this second value as the reference value.

The players' performance on the Upper Quarter Y Balance Test (UQYBT) did not significantly improve after using the sleeve. There was no bilateral difference pre-post test and no significant change for any direction (medial, inferiorlateral or superiorlateral) of the UQYBT. The entire kinetic chain is involved in the functional performance of this tests which may explain why the sleeve did not have an effect on the test outcome. Normative values for the UQYBT in rugby players have not been published, but composite scores on the dominant arms of overhead athletes (n=206, age range 18-25 years old) have been reported for volleyball, tennis and handball players (mean ±SD 90±6.91, 87.7±5.62, and 88.1±8.03, respectively) (Borms, Maenhout and Cools 2016). In the present study, the mean composite score was similar to the values for overhead athletes of the same age category. The sleeve did not confer any functional performance advantage to the players executing this task, which may also be partly due to the multiple interdependent components involved and the functional complexity of the task.

In addition to the effects of the sleeve on shoulder outcome measures, we used a patient-reported outcome measure for the shoulder, the Stanmore Percentage of Normal Shoulder Assessment (SPONSA), and collected players' subjective feedback about wearing the sleeve. The players did not notice an improvement in their shoulder function after using the sleeve when rated according to the SPONSA. As the SPONSA has not been used in an asymptomatic population there is not a valid comparator for these results. Players' feedback about the sleeve revealed both positive and negative wearing experiences. Most players' thought that the level of satisfaction of the sleeve to be "excellent", however some found that the proximal fit of the sleeve needed to be improved. This may have been due to the difference in girth of the players arms being much larger compared to a person following a stroke, for whom the sleeve would typically be used. Players also reported that the sleeve did not stay in place and resulted in some irritation. These issues are worth considering by the manufacturer for future testing of the sleeve in sporting populations. Despite these issues reported about the fit of the sleeve, the sleeve was worn for 90% of the time that was prescribed evidenced by the wearing record which indicates high adherence to using the sleeve.

Limitations

Interpretation of the results must be viewed within the limitations of the study. The small sample of rugby players used in this study is the greatest and means that the findings may not be generalizable. Future studies could focus on recruiting a larger sample of players, which would also be beneficial in gaining normative data on the shoulder outcome measures in this study. Secondly, using RTUS to view the AGT distance gives a 2-dimensional representation of the subacromial space and does not provide information about relative scapular movement. This could be addressed by concurrently evaluating scapulohumeral kinematics and using a 3D RTUS. The lack of suitable images using the novel RTUS method could have been due to the investigator's insufficient training and experience of to develop sufficient skill. Further training and experience of the investigator using RTUS could improve the quality of images produced.

There was a risk of measurement bias during pre-post testing by being unable to blind the evaluators to the study groups in addition to not carrying out reliability and validity tests of the outcome measures. It is acknowledged that it cannot be guaranteed that the players' isometric contraction efforts were their maximal efforts. The evaluators were blinded to dominant versus non-dominant arms, though, and the validity and reliability of the outcome measures used in this study (apart from the novel method to measure anterior humeral head translation) have been previously tested in other research. Calibration of all study instruments, training of the evaluators and pre-testing was carried out in our study to reduce the risk of bias. These steps are appropriate to reduce the misclassification of outcome measures in this study, but there may have been cases where this still occurred.

The threshold for the statistical significance testing in our study was 0.05 but multiple statistical testing with several endpoints is recognised as increasing the likelihood of a type I error (Akobeng 2016). Performing fewer shoulder function assessments in future research could also be considered to reduce the risk of type I error occurring. Reducing the tolerable type I error rate (0.01 instead of 0.05) is an approach that could be chosen to address this result. Doing this, however, is likely to increase the risk of type II error occurring unless a larger sample size was used. Due to the small sample size in this study the significance level was set at 0.5. The effects of the sleeve could be tested in a more sport-specific manner following simulated rugby tackling. Lastly, the compression sleeve could be worn for a longer period to determine if there is a larger effect and players could be tested with the compression sleeve on to investigate its effects.

Conclusion

This study evaluated a novel intervention (lycra sleeve) that has not been used in a rugby playing population to determine its effect on shoulder injury risk factors. The preliminary findings from this study is that some of the outcome measures (shoulder range of motion and shoulder instability and laxity) are sensitive enough to detect a change following use of the lycra compression sleeve. In general, detectable changes were seen in active shoulder external rotation range, passive shoulder internal rotation range, acromion-greater tuberosity distance and shoulder laxity outcomes. This intervention offers encouraging findings to warrant a full-scale study further determining its prophylactic role. Due to the small sample size recommendations to use the sleeve cannot be confidently made; however, these findings support a larger trial to confirm the effects of the lycra compression sleeve.

Chapter Eight

Discussion

Review of the aims

The series of studies in this thesis followed a sequence of steps to establish preventive measures to reduce the risk of shoulder injuries in rugby players. Through this approach, it aimed to summarise the body of knowledge pertaining to shoulder injury epidemiology in rugby and describe the process of developing a shoulder-specific injury prevention programme for use in community youth rugby. In so doing, this research provides new knowledge in considering the implementation context of such an intervention.

This research was undertaken with the acknowledgement that rugby injuries are multi-factorial (Bahr and Krosshaug 2005, Meeuwisse, Tyreman, Hagel et al. 2007) and that the warm up intervention developed in this thesis is one of many preventive strategies that can be employed. In response to calls to describe the implementation context of the intervention (Finch and Donaldson 2010, Finch 2011, Donaldson and Finch 2012, Hanson, Finch, Allegrante et al. 2012, Hanson, Allegrante, Sleet et al. 2014, O'Brien and Finch 2014, Verhagen, Voogt, Bruinsma et al. 2014, Donaldson, Lloyd, Gabbe et al. 2017, Vriend, Gouttebarge, Finch et al. 2017), this study is the first to investigate the psychosocial factors affecting community youth rugby coaches' and players' adherence to a warm-up programme. In doing so, the relevance of this research is considered in terms of the barriers and facilitators to community youth coaches and players adopting and sustaining this preventive intervention. In addition, a secondary aim and novelty of this research was to evaluate the feasibility of using health technology in the form of a lycra compression sleeve, to determine if it could favourably modify risk factors associated with shoulder injuries in rugby players.

Shoulder injury epidemiology

Approximately 359,447 rugby players are registered in England, with community rugby players representing a significantly larger proportion than professional players. In England, adult community rugby has one of the largest and longest running community level rugby injury surveillance projects in the world. The comprehensive epidemiological study detailed in chapter three presents the incidence and nature of shoulder injuries at this playing level (total of 239 club seasons), which corresponds to the first step of the TRIPP model and provides a baseline comparison for other community playing levels in rugby. An advantage of this study was that the data collected abides by the consensus statement for injury surveillance in rugby (Fuller, Molloy, Bagate et al. 2007) which allows for comparability with other studies following this method. Additionally, this is the first focused epidemiological study describing shoulder injury data over four seasons (2009-2013) and across three community rugby playing levels (semi-professional, amateur and recreational) where the majority of previous research focused on one cohort or playing level. Shoulder injuries have not been previous categorizing to this extent by outlining the injury type, playing level and on-field position in adult community rugby. Importantly, these findings permit targeted interventions to be introduced to address the most common shoulder injuries in the playing levels at greatest risk.

The ability to collect injury surveillance data on such a large scale is resource intensive, requiring injury data collectors at each club to have the appropriate level of qualification to provide valid injury diagnoses (Yeomans, Comyns, Cahalan et al. 2018). This draws attention to a limitation of this reporting method, as it is not practically adopted at playing levels where such resources do not exist. Community youth clubs, for example, do not benefit from having such resources available to them, making it difficult to ascertain the severity of injuries (Ekegren, Donaldson, Gabbe et al. 2014) and therefore requiring a different surveillance method to support reliable injury data collection. Recognising this limitation led to self-reported injuries using text messaging to be trialled in chapter seven in an attempt to address an acknowledged gap in the ability to gather injury data for epidemiological research in youth rugby.

The second step of the TRIPP model calls for the aetiology and mechanism of injury to be identified to help inform preventive strategies. The descriptive epidemiological study in chapter three focused specifically on shoulder injuries and identified a number of extrinsic risk factors that reinforce similar injury trends seen in rugby. The highest playing level (semi-professional players) had the highest incidence of 2.8 injuries per 1000 hours (both medical attendance and time-loss injuries), which was significantly higher than the recreational players, specifically for acromioclavicular joint injuries. This injury rate is comparable to knee injuries (2.8 injuries per 1000 hours) and higher than head injuries (2.0 injuries per 1000 hours) reported for all playing levels in adult community teams (Roberts, Trewartha, England et al. 2013). This highlights the magnitude of shoulder injuries at this level, revealing an urgent need for researchers, healthcare and conditioning specialists to address this injury problem. Notably, this study in this thesis, reported shoulder injuries that resulted in more than 8 days of time-loss which accounts for higher incidence reported elsewhere (Schwellnus, Jordaan, Janse van Rensburg et al. 2019). As the tackle was the main event associated with injury, during which the tackler was most injured, it warrants conditioning the shoulder to withstand these repeated impacts. Shoulder sprain and dislocation accounted for the highest incidence for all groups, with the suboptimal shoulder joint alignment and poor tackle technique being recognised as the mechanism of injury in other research (Longo, Huijsmans, Maffulli et al. 2011, Usman, McIntosh and Frechede 2011, Horsley and Herrington 2014). Neuromuscular training may therefore offer the potential to optimise shoulder conditioning to effectively withstand repeated impact during collisions and reduce the risk of injury.

Measurement reliability

Aetiological research investigating intrinsic risk factors depends on reliable assessment methods to accurately identify musculoskeletal dysfunction. The ability to reliably identify these risk factors is also limited by the level of experience of the raters. Chapter four showed that common tests used to evaluate the orientation of the scapula and clavicle by novice and experienced raters had poor to moderate reliability in rugby players. Other studies have shown similar results (Wright, Wassinger, Frank et al. 2013, Lange, Matthijs, Jain et al. 2017), but few have compared novice raters to experienced and none have been evaluated in a rugby playing population. These findings are relevant as they highlight the limitations that exist in accurately identifying players with impairments of the scapular position and motion. Furthermore, this study brings into question the clinical decision-making process when evaluating the shoulder girdle with observation alone. In light of the study findings, these clinical tests used in this study to evaluate the orientation of the shoulder girdle should not be used irrespective of the level of experience of the therapist. Potentially using a simplified test that has fewer categories to rate could be evaluated in future research involving novice raters to determine its reliability (Struyf, Nijs, Mottram et al. 2014).

Relating to the TRIPP model, this study did not explicitly fulfil step two, but it provided the necessary justification to rule out the assessment of the scapula as a test to identify shoulder injury risk factors. Irrespective of the level of experience of the rater, it is unreliable in identify shoulder girdle impairments in rugby players. In addition, while there are a number of benefits of pre-participation screening such as detecting existing health conditions, baseline testing and to review medication and supplements (Ljungqvist, Jenoure, Engebretsen et al. 2009), it is unlikely that musculoskeletal screening will be able to predict athletes at high risk of sustaining a future injury (Bahr 2016, Whittaker, Booysen, De la Motte et al. 2017). This signifies a shift in our understanding about the benefits of athlete screening which previously recommended that research be conducted on screening to identify athletes at risk and intervene to change outcomes (Ljungqvist, Jenoure, Engebretsen et al. 2009). A meaningful debate is being deliberated regarding the effectiveness and efficiency of screening tests which outlines some of the complexities involved with its role in injury prevention (Bahr 2016, Hewett 2016, Whittaker, Booysen, De la Motte et al. 2017, Verhagen, van Dyk, Clark et al. 2018). It is argued that there is value in continuing to offer screening assessments to determine which combination of tests are most useful in which context, and also to incorporate repeated measures and monitoring of variables over time (Verhagen, van Dyk, Clark et al. 2018). A fundamental issue that needs to be pointed out is the importance of the context in which worthwhile screening can feasibly take place. In the community youth rugby context where the coach is usually a parent of a child in the team, and is also likely to be the first aider having done a basic level qualification, it is practically impossible to meet these recommendations for screening (Donaldson and Finch 2012). Since there is minimal cost and discomfort to the athlete, the benefits of neuromuscular training programmes should be targeted to community youth rugby players and not based on those at-risk athletes as identified by screening tests.

Describing the implementation context

There is a strong body of evidence that shows neuromuscular training programmes are efficacious when used in a number of different sports (Emery, Roy, Whittaker et al. 2015, Thorborg, Krommes, Esteve et al. 2017). These benefits have also been demonstrated in rugby (Hislop, Stokes, Williams et al. 2017, Attwood, Roberts, Trewartha et al. 2018); however, neuromuscular training programmes suffer from poor adoption across all sport (Soligard, Nilstad, Steffen et al. 2010, Finch, Diamantopoulou, Twomey et al. 2014). Informed by the strength of the existing body of evidence on neuromuscular training programmes, this thesis advanced to step five and six of the TRIPP model. These steps advise describing the facilitators or barriers to intervention adoption in the target population and evaluating the effectiveness of the preventive measure in the implementation context. Chapter five detailed the process of formulating an evidence and theory-based shoulder-specific injury prevention routine and thereby responded to the fact that there is limited research available to guide the development process of an injury prevention intervention. The importance of developing evidence-informed and context-specific interventions is considered an essential requirement to advance the field of sport injury prevention, helping to maximise their impact in real-world settings (Finch 2011, Donaldson, Lloyd, Gabbe et al. 2016). Outlining this process in chapter five contributes to the literature in this field by providing guidance to other researchers on the fundamental steps used to develop an intervention that balances research evidence with practitioner expertise and end users experience in the implementation context.

This shoulder-specific warm up for rugby used research evidence to formulate a programme that was agreed to be appropriate and suitable by the multi-disciplinary technical project group, stakeholders, and together with input from a feasibility trial was implemented in a pilot study for community youth rugby players. Specifically, in this setting, evidence-based shoulder-specific preventive exercises that are functional and integrates kinetic chain movements without the need for any specialised equipment are deemed to be time efficient and less likely to deter engagement with the intervention. It proved prudent to involve practitioners and researchers in the technical project group who were respectively active in youth rugby and sport injury prevention research as their expert input provided insight to the exercise structure and selection. Engaging with end users (coaches and players) in the development process of the intervention is vital to gain their support as co-creators of the intervention that they are intended to adopt and sustain in practice (Donaldson and Finch 2012). This approach is anticipated to increase the likelihood of empowerment and ownership of the problem and solution by the end user. A coach-driven preventive intervention was identified by the stakeholders as the best method to deliver the IPEP and this is also echoed in the literature for sport injury prevention at this playing level (Finch and Donaldson 2010, Finch, Diamantopoulou, Twomey et al. 2014, White, Otago, Saunders et al. 2014). The knowledge gained from this study helps to understand the systems and processes in place for injury prevention in community youth rugby teams. Trialling the intervention was useful in refining the technical aspects of the programme delivery and appropriateness of the sequence of exercises. This is not only useful to enhance the translation of evidence into practice, but also the steps taken can be followed as a suitable approach in promoting the development of preventive strategies amongst target groups in future research. It is by doing this that a better understanding of how the adopters of injury prevention interventions perceive and interpret preventive strategies within the real-world. The implications from this study are directly relevant to shoulder injury prevention in community youth rugby players and provided a more comprehensive understanding about developing a shoulder-specific injury prevention warm up routine in real-world settings.

Chapter six evaluated the feasibility of, and adherence to, the shoulder-specific injury prevention warm up intervention in community youth rugby. Most importantly, this study provided new knowledge about the acceptance of the intervention amongst community youth rugby coaches and players, allowing it to be tailored to encourage maximum participation and effectiveness. The perceptions of the programme coaches are essential to understand as they ultimately influence the health-beneficiaries' (players) adoption of the programme at this playing level (McKay, Steffen, Romiti et al. 2014, O'Brien and Finch 2017). Consequently, coaches need to be well informed about their role and the role of the parent in injury prevention (Emery, Hagel and Morrongiello 2006, Finch, Diamantopoulou, Twomey et al. 2014), supported by wider dissemination of preventive strategies being made more accessible to coaches and enabling them to feel confident as delivery agents. This illustrates a need to evaluate effective methods to promote the preventive benefits of neuromuscular training through multiple different formats.

Additional time cannot be manufactured to address the commonly reported time constraint limiting inclusion of the routines during training (Donaldson, Lloyd, Gabbe et al. 2017), but promoting the value of preventing players from being injured may encourage greater adoption (Fuller 2019). A culture change is necessary that creates and promotes an acceptance that injury prevention is as important to focus on as the team's competition results. Identifying what works best to address these behavioural complexities to adopting preventive interventions is an emerging area of injury prevention research, with no definitive solution established. Self-efficacy, relating to the coaches' confidence that they understand and are able to use the warm up programme is being shown to be positively related to their intention to implement the intervention (Owoeye, Bulat, McKay et al. 2017). Opportunities to develop this could be considered in coach workshops that aim to enhance self-efficacy. It is worth future studies addressing negative perceptions at the onset by educating players and coaches early about the benefits of neuromuscular training (Finch, Donohue and Garnham 2002, Verhagen and van Mechelen 2010). Addressing these injury prevention adoption issues early with youth players may help in creating safer behaviour as they get older, using routine practice with progression built in.

In response to the significant issue raised regarding the lack of sport injury surveillance at lower playing levels, the study in chapter six also successfully utilised text messaging for injury reporting and recording compliance with the intervention. The higher response rate and injuries captured using SMS compared to coach reported is supported by existing evidence in the field that captured self-reported injuries using SMS (Ekegren, Donaldson, Gabbe et al. 2014, Ekegren, Gabbe and Finch 2014, Nilstad, Bahr and Andersen 2014, Moller, Wedderkopp, Myklebust et al. 2018), aligning to the future sport injury prevention research priorities (Finch, Bahr, Drezner et al. 2017). Collectively this evidence supports the feasibility of using this method in settings where limited resource challenges exist, such as in community youth rugby and addresses a problem where the true incidence of injury may be under-reported (van Beijsterveldt, Stubbe, Schmikli et al. 2015). The significance of shoulder injuries to youth players presented in the literature review of this thesis is based on data from infrequent studies, though it provides a valid justification to support the need for an ongoing surveillance system to track injuries incurred by youth players. It is detrimental that injury surveillance in youth rugby is not mandatory and only considered when it is part of a research study of limited duration, and an ongoing surveillance system has not yet been established. Granted that there are impediments that may explain why the systems used at the adult playing level are not being continuously applied to the youth setting (Ekegren, Gabbe and Finch 2016), but if injury prevention is to be embedded at this playing youth level, there absolutely needs to be an appropriate means of reporting. Self-reported injury using SMS is appearing to be a viable option to injury surveillance in community youth rugby. This finding is practically meaningful as it addresses a significant obstacle to injury data collection where there is a lack of suitable injury reporting systems available, especially in community youth settings.

The benefits of the SMS reporting system also allowed for the adherence to the intervention to be monitored. Moreover, this surveillance method may serve to encourage players to do the preventive warm up routine which could increase programme adoption. Fortnightly injury prevention advice provided to athletes may serve as a useful prompt to athletes compared to only providing injury prevention advice at baseline. Individual athlete advice, at the time of injury, about preventing recurrent injury and gradual return to play may also be possible using this SMS system. This approach was used with trail runners (n=232) who sustained 13% fewer running related injuries when sent specific advice on prevention every two weeks (Hespanhol, van Mechelen and Verhagen 2018). Though SMS data collection must be overseen by a research officer, it is less resource intensive than having data collectors at every team participating in injury surveillance. These findings should be used when attempting to increase the use of this type of injury surveillance system which will allow for the data to better represent the extent of the injury problem in the target population, ultimately informing preventive strategies.

Lycra compression sleeve

The use of health technology in the form of a lycra compression sleeve was evaluated for the first time in rugby players (chapter seven) and represents a novel contribution to this field of research. In particular, it tested a lycra compression sleeve to explore whether the favourable effects seen in people with neurological conditions would also occur in a rugby playing population. This small feasibility study showed that the following outcome measures were able to detect change between groups in active shoulder external rotation range and passive shoulder internal rotation range, and there were some positive trends seen on the acromion-greater tuberosity distance and shoulder laxity outcomes. Considering that players with deficits in shoulder rotational range of motion (Fernandez, Aravena, Verdugo et al. 2011, Horsley, Pearson, Green et al. 2012, Bolton, Moss, Sparks et al. 2013, McDonough and Funk 2014) and players with loose or hypermobile shoulders (Stewart and Burden 2004, Cheng, Sivardeen, Wallace et al. 2012, Ogaki, Takemura, Iwai et al. 2014, Owens, Campbell and Cameron 2014) have been shown to be at greater risk of shoulder injuries, the implications from these findings using the sleeve are favourable. The findings support a larger trial to confirm these effects, which would have clinical and practical implications for shoulder injury prevention and management options. In addition, research could evaluate using the sleeve as an adjunct to exercises that have shown to have great value in conservative management for shoulder instability (Watson, Balster, Lenssen et al. 2018).

Future directions

Given the importance of developing injury prevention programmes specifically suited to the implementation context, there will generally be a need to continue to develop new preventive exercise programmes or to adapt existing efficacious ones. The process outlined in this study to develop a preventive programme for community youth rugby could be used to contribute to the generation of consensus guidelines to outline which process should be followed in such a framework.

The injury surveillance method used in chapter six is of significant value as it contributes to the evidence supporting its usage by providing a reliable and affordable solution to injury reporting where resources are limited. Further developing and researching methods such as self-reported text messaging may allow sport injury epidemiological research to overcome the hinderance faced in establishing the size of the problem in community youth playing levels. Injury self-reporting via SMS represents a feasible surveillance method to research in community youth sport and school sport settings. Clearly, there is a risk of misclassification of the self-reported injuries which would need to be further evaluated and validated by medical staff in future research. The use of SMS technology in sport injury prevention is in its infancy and there is great scope to expand its use in injury surveillance.

Perhaps the most profound findings from this research come from its consideration of a bottom-up approach to implementation by involving the stakeholders and end users from the beginning of the development process of an injury prevention intervention. This is considered fundamental in understanding the complexities of adherence to the intervention and is when research starts to be translated into practice. This invaluable information may be used to inform a larger cluster randomised control trial. Effective promotion of the benefits of neuromuscular training programmes amongst stakeholders and end users as well as comprehensive coaching workshops to enhance self-efficacy in doing the warm up routines are a few areas to target in future research. Targeted use of SMS system alongside a preventive intervention is another proposed method to encourage adoption of preventive methods.

Limitations

Sample size is recognised as a limitation of each of the studies in this thesis. Recruitment posed a challenge, especially amongst the younger playing level, though through this experience future recruitment strategies are to be considered. For example, the use of prepaid return envelops could be sent out with participation information sheets to players' parents allowing for the completed forms to be returned. The sample size could be further increased by including a wider age range for youth teams and also including rugby playing schools from a larger geographical area. This might result in teams participating with varying levels of resource and support available to them which may influence their adoption of the preventive measures. In addition, the regional and national governing body for rugby could make it a requirement for clubs to participate in future research would undoubtably bring with it an increased cost and research administration requirement which needs to be guided by determining a suitable sample size using a power calculation and balanced with the analytical decisions on the statistical power of the study such as a more stringent significance threshold. Generalisability of the findings in these studies is also a potential limitation due to the small sample sizes. As the majority of the studies were conducted in junior playing level, it cannot be stated with certainty that the findings can be applied to other rugby age groups or settings.

The validity of the data collected using the SMS self-reported injuries was not evaluated to determine if the reported injuries were reliable. Both injury registration methods reported by the coach and self-reported by the player exposes a limitation of this study not being able to record a specific injury diagnosis. Future research could follow up reported injuries and conduct a telephone / video call injury triage, by a suitably qualified person, to determine the accuracy of the injury site reported. There will however be an upper limit on the size of the cohort that can be involved in this injury registration method. In studies with very large cohorts or where there is a lack of resources, an alternative approach could be to collect self-reported information from players that focuses on the degree of symptoms experienced and the consequence sport participation, training volume and performance.

Collecting match and training exposure at the team level limits the ability to account for individual players who are involved with other teams (school or academy level). The cumulative effect of their exposure to all rugby is harder to track, logistically challenging and resource demanding which poses an interesting area for future research to evaluate the overall player training load from all rugby involvement.

Thesis conclusions

This series of studies has shown that shoulder sprain and dislocation accounted for the highest incidence across adult community players. Reviewing the literature relating to shoulder injuries across all playing levels has highlighted that youth academy players sustain a higher incidence than adult community players. The complexities of monitoring and addressing injuries at this level needs focused efforts to prevent and manage the injury risk at this level.

Reliability of observational evaluation of the scapula is poor to moderate, irrespective the level of experience of the therapist. The use of self-reported injuries using SMS is a viable consideration for this playing level and offers the potential to widen the scope for its inclusion in injury surveillance in community youth rugby. The shoulder-specific injury prevention intervention provided important new information on the perceptions and beliefs of coaches and players in community youth rugby. Specifically, that adherence is better when the coach is the delivery agent of the intervention at this level. Future opportunities to increase the adoption of injury prevention should explore a range of methods to promote the benefits of injury prevention that stresses its value to the same extent that competition results are given importance. A clear negative associations between injury burden measures and teams success (70-100% likelihood) has been shown within professional rugby teams (Williams, Trewartha, Kemp et al. 2016) and in professional European soccer teams (Hagglund, Walden, Magnusson et al. 2013) which stresses the value of educating clubs about injury prevention to increase a teams' chances of success. The role of behavioural change approaches in the research is currently under investigation to get more players to do the preventive interventions that are proven to work. The outcome measures used in the lycra compression sleeve study seems sensitive to detect change on a number of physiological measures such as shoulder range of motion and shoulder laxity. These findings together with player adherence to wearing the sleeve supports the feasibility of a larger study to evaluate the effects.

The findings of this thesis add to the body of literature by advancing the understanding of shoulder injury risk and prevention in youth rugby players, and provides important and impactful implications for translating shoulder injury prevention research into practice in this population.

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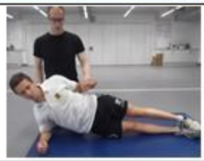
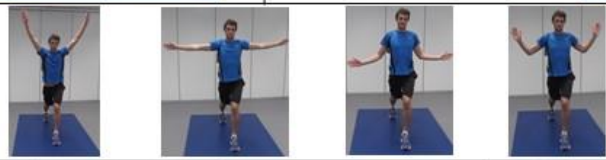
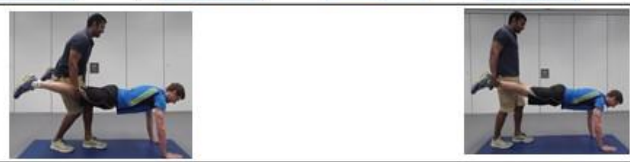
Appendix A: Part two of the Rugby Activate Shoulder Injury Prevention Programme (Chapter 5)

PART TWO (8 minutes)		
Level 1	**Level 2**	**Level 3**
Trunk rotation: 3 x 8-16 reps 	**Dynamic W stretch:** 3 x 8 -16 reps	**Squat rotation:** 3x 8-16 reps 
Hip bridge: 2 reps 	**Single leg bridge:** 2sets 	**Nordic hamstring:** 3-5 reps 
Shoulder side lying plank: 2 sets 	**Lunge with Y, T, L, W:** 2sets 	
Bear crawl: 2 sets 	**Wheelbarrow:** 1 set 	
Neck strength: 1 set 	**Neck strength:** 1 set 	
Plank ball rolling: 2x10 rolls 	**Push up taps:** 2x15secs 	**Clap press-up:** 2x 6-8 reps 

Appendix B: Participant information and consent form (Chapter 6)

The effectiveness of a warm up programme to prevent injuries in community youth rugby union

Coach's information sheet

Principal Investigator: Dr Carly McKay

Other investigators: Dr Keith Stokes, Mr Vincent Singh

We would like to invite you to participate in this study where we are testing how well a new warm up routine can get your players ready for rugby and reduce their chances of getting injured. The following information tells you why we are doing the study and how it will affect you. Please take your time to read the information carefully and if there is anything that you do not understand please speak to a member of the research team. You are also welcome to contact us directly for any further information. Once you have read and understood the information, and if you wish to be in the study, you will be need to sign the coach consent form.

Background to the study
Research has shown in other sports that specially designed warm up programmes can significantly reduce injuries suffered by players, however this injury reduction has not yet been demonstrated in youth rugby players. Also, it is true that these special warm ups are not always taken up by sport teams in their normal training routines. We are interested to see if we can discover more about the factors affecting how much the warm up programme is used during a season and how well it is reducing injuries. In doing so it will help us to better understand how rugby teams like to prepare for training and matches.

What does the study involve?
We will visit your club at the beginning of the season to introduce the coaches to the warm up programme. Coaches will then deliver a 10 – 15 minute warm up routine to their teams at the beginning of each training and match session. During the course of the season your players' parents will be sent a weekly SMS to find out if their child played a rugby match and whether their child had an injury that caused them to miss a day's training or more. Parents will be asked to reply to an SMS asking if their child completed the warm up routine during training and or before matches. At the beginning and end of the season we will ask your players' parents to complete a short online questionnaire with your players which asks a few questions about what your players prefer to do during your rugby warm ups. This information will then be analysed by researchers at the University of Bath.

Who are we asking to participate?
All rugby players in the U15 – U18 squads in a number of clubs in England.

Do I have to take part?
No, it is not compulsory to participate. It is up to you to decide whether you would like to take part. The more players and coaches that do take part help us to make better recommendations about the best ways for rugby players to prepare for rugby and fully enjoy the sport. If you decide to take part you will need to sign a consent form that confirms you have read this information and you agree to participate in the study. You may withdraw from the study at any time and without a reason by contacting us.

Players will also be asked to sign the form and we request that they take a copy of the form to their parent / legal guardian to ask them to agree their participation.

What do coaches have to do?

1. At the beginning and end of the study, coaches will be asked to complete a short online questionnaire which asks a few questions about what they prefer to do during their rugby warm ups.

2. During the study the research team will visit coaches to show them how to deliver the warm up routine. Following this, coaches will be asked to deliver the warm up routine to their teams at the beginning of their training and match sessions during the season.

3. Coaches will also be asked to submit a weekly reporting form which will be used to determine exposure data (player attendance and warm up completion) and injuries that occurred during that week. The research team will visit teams periodically during the season to collect forms and ensure that all study-related questions are answered.

What do your players have to do?

1. At the beginning of the season we will come to one of your rugby training sessions and collect some information about your players (date of birth, height, weight, rugby playing history) and parent mobile numbers and email addresses.

2. If they agree to participate in this project, players should complete the warm up routine which will be delivered by their coach at the beginning of every training and match session during the season. Players' parents will be asked to reply to an SMS asking if their child completed the warm up routine during training and or before matches.

3. During the season, players' parents will be asked to reply to one SMS text per week asking if their child did or did not sustain an injury from rugby participation that meant that they could not train or play fully in the next session.

4. Team parents will also be sent a short online survey at the start and end of the season with questions for them to complete along with their child, asking their views about what their child prefers in their rugby warm ups.

Are there any risks from taking part?
There are no anticipated risks to you for being involved in this study.

Will information about me be kept confidential?
We will follow the Data Protection Act which means that we must have your permission to collect information about your test results during the course of this study. All information collected is anonymised and stored using a code number rather than your name. The results will be reported back to you but in other reports your identity will not be able to be recognised. Parents' and coaches' mobile numbers and email addresses will be requested, held and used for study-related communication only.

What will happen to the information of the study?
Researchers at the University of Bath will analyse the information and produce a report. The report will describe how well the warm up programmes work and what players and coaches like and don't like about them. No personal references will be made in any report.

The effectiveness of a warm up programme to prevent injuries in community youth rugby union

Coach consent form

I have read and understood the information about this study and I have had a chance to ask questions.

I agree to take part in the study and give consent for researchers to contact me using email. I agree that the information will only be used for research purposes and in a report to my club. Information in which I can be identified will only be made in feedback to me.

I understand that I can withdraw from this study at any time without being asked why.

Participant:

Name	Date	Signature

Mobile number	Email address

Researcher taking consent:

Name	Date	Signature

OFFICE USE ONLY	
CLUB	
COACH PROJECT ID	
COACH SEASON ID	

In the event that you longer wish to participate in the study, please tick one of the boxes below:

I am happy for any data collected from me to be used by the researchers	☐
I am not happy for any data collected from me to be used by the researchers	☐

The effectiveness of a warm up programme to prevent injuries in community youth rugby union.

Parents information sheet

Principal Investigator: Dr Carly McKay

Other investigators: Dr Keith Stokes and Mr Vincent Singh

We would like to invite you to participate in this study where we are testing how well a new warm up routine can get your child ready for rugby and reduce their chances of getting injured. The following information tells you why we are doing the study and how it will affect you. Please take your time to read the information carefully and if there is anything that you do not understand please speak to the people responsible for your child's rugby team (coach/ trainer). You are also welcome to contact us directly for any further information. Once you have read and understood the information and if you wish to be in the study you will be need to sign the parent consent form.

Background to the study

Research has shown in other sports that specially designed warm up programmes can significantly reduce injuries suffered by players, however this injury reduction has not yet been demonstrated in youth rugby players. Also, it is true that these special warm ups are not always taken up by sport teams in their normal training routines. We are interested to see if we can discover more about the factors affecting how much the warm up programme is used during a season and how well it is reducing injuries. In doing so it will help us to better understand how rugby teams like to prepare for training and matches.

What does the study involve?

We will visit your child's club at the beginning of the season to introduce the coaches to the warm up routine. Coaches will then deliver a 10 – 15 minute warm up routine to their teams at the beginning of each training and match session. During the course of the season weekly rugby injuries that caused players to miss a day's training or more will be recorded. This information will be obtained from data reported from coaches and will also include injuries reported by parents of players via text messaging. Parents will be asked to reply to an SMS asking if their child completed the warm up routine during training and or before matches. At the beginning and end of the season we will ask parents to complete a short online questionnaire with your child which asks a few questions about what your child prefers to do during rugby warm ups. This information will then be analysed by researchers at the University of Bath.

Who are we asking to participate?

All rugby players in the U15 – U18 squads in a number of clubs in England.

Do I have to take part?

No, it is not compulsory to participate. It is up to you to decide whether you would like to take part. The more players and coaches that do take part help us to make better recommendations about the best ways for rugby players to prepare for rugby and fully enjoy the sport. If you decide to take part you will need to sign a consent form that confirms you have read this information and you agree to participate in the study. You may withdraw from the study at any time and without a reason by contacting us. Players will also be asked to sign the form and we request that they take a copy of the form to their parent / legal guardian to ask them to agree their participation.

What do parents have to do?

4. At the beginning and end of the study parents will be asked to complete a short online questionnaire which asks a few questions about what your child prefers to do during rugby warm ups.

5. During the season we will ask that parents reply to one SMS text per week asking if their child did or did not sustain an injury from rugby participation that meant that they could not train or play fully in the next session. Parents will also be asked to reply to an SMS asking if their child completed the warm up routine at training or a match. We will require the mobile numbers of parents to enable us to do send these text messages.

What does your child have to do?

5. At the beginning of the season we will come to one of your rugby training sessions and collect some information about your child (date of birth, height, weight, rugby playing history) and parent mobile numbers and email addresses.

   If your child agrees to participate in this project, they should complete the warm up routine which will be delivered by their coach at the beginning of every training session and match during the season.

6. Parents will also be sent a short online survey at the start and end of the season with questions for them to complete asking their child's views about what their child prefers in their rugby warm ups.

Are there any risks from taking part?
There are no anticipated risks to you for being involved in this study.

Will information about me be kept confidential?
We will follow the Data Protection Act which means that we must have your permission to collect information about your test results during the course of this study. All information collected is anonymised and stored using a code number rather than your name. The results will be reported back to you but in other reports your identity will not be able to be recognised. Parents' and coaches' mobile numbers and email addresses will be requested, held and used for communication to participants.

What will happen to the information of the study?
Researchers at the University of Bath will analyse the information and produce a report. The report will describe how well the warm up programmes work and what players and coaches like and don't like about them. No personal references will be made in any report.

Enquiries:
Should you have any further queries about this study, please contact Vincent Singh (tel: 07894129702; v.singh@bath.ac.uk; Applied Biomechanics Suite 1.308, University of Bath).

The effectiveness of a warm up programme to prevent injuries in community youth rugby union.

Parent consent form

I have read and understood the information about this study and I have had a chance to ask questions.

I agree to take part in the study and give consent for researchers to contact me using email. I agree that the information will only be used for research purposes and in a report to my club. Information in which I can be identified will only be made in feedback to me.

I understand that I can withdraw from this study at any time without being asked why.

Participant:

Name	Date	Signature

Mobile number	Email address

Researcher taking consent:

Name	Date	Signature

OFFICE USE ONLY	
CLUB	
COACH PROJECT ID	
COACH SEASON ID	

In the event that you longer wish to participate in the study, please tick one of the boxes below:

I am happy for any data collected from me to be used by the researchers	☐
I am not happy for any data collected from me to be used by the researchers	☐

The effectiveness of a warm up programme to prevent injuries in community youth rugby union.

Player information sheet

Principal Investigator: Dr Carly McKay

Other investigators: Dr Keith Stokes, Mr Vincent Singh

We would like to invite you to participate in this study where we are testing how well a new warm up routine can get you ready for rugby and reduce your chances of getting injured. The following information tells you why we are doing the study and how it will affect you. Please take your time to read the information carefully and if there is anything that you do not understand please speak to the people responsible for your team (coach/ trainer). You are also welcome to contact us directly for any further information. Once you have read and understood the information and if you wish to be in the study you will be need to sign the Player Consent Form, which will be counter-signed by your rugby coach and parent / guardian.

Background to the study

Research has shown in other sports that specially designed warm up programmes can significantly reduce injuries suffered by players, however this injury reduction has not yet been demonstrated in youth rugby players. Also, it is true that these special warm ups are not always taken up by sport teams in their normal training routines. We are interested to see if we can discover more about the factors affecting how much the warm up programme is used during a season and how well it is reducing injuries. In doing so it will help us to better understand how rugby teams like to prepare for training and matches.

What does the study involve?

We will visit your club at the beginning of the season to introduce your coaches to the warm up programme. Coaches will then deliver a 10 – 15minute warm up routine to their teams at the beginning of each training and match session. During the course of the season weekly rugby injuries that caused players to miss a day's training or more will be recorded. This information will be obtained from data reported from coaches and will also include injuries reported by parents of players via text messaging. Parents will be asked to reply to an SMS asking if their child completed the warm up routine during training and or before matches. At the beginning and end of the season we will ask your parents to complete with you a short online questionnaire with you which asks you a few questions about what you prefer to do during your rugby warm ups. This information will then be analysed by researchers at the University of Bath.

Who are we asking to participate?

All rugby players in the U15 – U18 squads in a number of clubs in England.

Do I have to take part?

No, it is not compulsory to participate. It is up to you to decide whether you would like to take part. The more players that do take part help us to make better recommendations about the best ways for rugby players to prepare for rugby and fully enjoy the sport. If you decide to take part, you will need to sign a consent form that confirms you have read this information and you agree to participate in the study. You may withdraw from the study at any time and without a reason by contacting us. We will also ask your coach to sign the form and request that you take a copy of the form to your parent / legal guardian to ask them to agree your participation.

What do players have to do?

1. At the beginning of the season we will come to a rugby training session and collect some information about you (date of birth, height, weight, rugby playing history) and parent mobile numbers and email addresses.

2. If you agree to participate in this project, you should complete the warm up routine which will be delivered by your coach at the beginning of every training session and match during the season. Players' parents will be asked to reply to an SMS asking if their child completed the warm up routine during training and or before matches.

3. During the season we will ask that parents reply to one SMS text per week asking if their child did or did not sustain an injury from rugby participation that meant that they could not train or play fully in the next session.

4. Parents will also be sent a short online survey at the start and end of the season with questions for them to complete asking their child's views about what their child prefers in their rugby warm ups.

Are there any risks from taking part?

There are no anticipated risks to you for being involved in this study.

Will information about me be kept confidential?

We will follow the Data Protection Act which means that we must have your permission to collect information about your test results during the course of this study. All information collected is anonymised and stored using a code number rather than your name. The results will be reported back to your coaching staff at your club but in other reports your identity will not be able to be recognised. Parents' and coaches' mobile numbers and email addresses will be requested, held and used for communication to participants.

What will happen to the information of the study?

Researchers at the University of Bath will analyse the information and produce a report. The report will describe how well the warm up programmes work and what players and coaches like and don't like about them. No personal references will be made in any report.

Enquiries:

Should you have any further queries about this study, please contact Vincent Singh
(tel: 07894129702; v.singh@bath.ac.uk; Applied Biomechanics Suite 1.308, University of Bath).

The effectiveness of a warm up programme to prevent injuries in community youth rugby union.

Player consent form

I have read and understood the information about this study and I have had a chance to ask questions.

I agree to take part in the study and give consent for researchers to contact me using short messaging service and email and for basic details of any injury I sustain while playing rugby to be recorded. I agree that the information will only be used for research purposes and in a report to my club. Information in which I can be identified will only be made in feedback to me and to coaching staff at my club.

I understand that I can withdraw from this study at any time without being asked

Participant:

Name	Date	Signature

For participants aged under 18 years on the first day of the playing season:
Coach (in loco parentis):

Name	Date	Signature

For participants aged under 18 years on the first day of the playing season:
Parent / Guardian:

Name	Date	Signature

Additional information for use in the study
To allow us to perform an indirect estimation of each player's maturation status, please complete the following:

Biological Mother's Adult Height   Biological Father's Adult Height
(please use either feet/inches or cm units whichever you prefer)

Only for those needing to re-consent
For participants who turn 18 years during the study period to re-consent to participation:

Name	Date	Signature

Researcher taking consent:

Name	Date	Signature

OFFICE USE ONLY	In the event that you longer wish to participate in the study, please tick one of the boxes below:
CLUB	
PLAYER PROJECT ID	I am happy for any data collected from me to be used by the researchers
PLAYERS SEASON ID	I am not happy for any data collected from me to be used by the researchers

Appendix C: Rugby Activate 2016 – 2017 Weekly Reporting Form (Chapter 6)

Age Group:	Club/Team:	*Office use only*

Rugby Activate Components			Completed ✓ Training	Completed ✓ Match
Warm-up duration: (minutes)	**Part 1** Running Exercises	1. British Bull dog		
		2. Hip out		
		3. Hip in		
		4. Circling partner		
		5. Shoulder contact		
Training: ________ / **Match:** ________		6. Quick forwards and backwards		
	Part 2 Strength, Plyometric, Balance **(please circle as appropriate)**	7. Trunk rotation, Dynamic W stretch, squat rotation		
		8. Hip bridge, Single leg bridge, Nordic		
		9. Shoulder side plank, lunge Y, T, W, .		
		10. Bear crawl, wheelbarrow		
		11. Neck strength		
		12.Plank ball roll, push up taps, clap press up		
	Part 3 Running Exercises	13. Across the pitch		
		14. Bounding		
		15. Plant and cut		
			Training	Match
Total number of players in training session ________	**Did any players not do the warm up?**			

Rugby Injury reporting

Player Id	Playing position	Body part injured (include left or right)	How did the injury happen?	During Training	During Match

Appendix D: Pre-intervention questionnaire (Chapter 6, (Coach version))

Coach's Name: ______________________ Date: __________________
Club & Team Name: ____

Thank you for taking the time to complete this survey which should take you 10-15 minutes to complete.

SECTION A: Coach's participation and Injury History

Please answer the following questions providing brief details where appropriate.

Previous rugby coaching history:

1. How many years have you been coaching rugby?

Less than 1 year	1-3 years	4-6 years	7-9 years	More than 10 years

2. What is the highest level of coaching that you have ever coached in?

School/club	County	Divisional	Academy	International	Not applicable

3. Which level did you coach in during the 2015-2016 season? (indicate more than one if appropriate)

School/club	County	Divisional	Academy	International	Not applicable

4. Approximately how many hours of coaching did you participate in during training and games per week during the 2015-2016 season?

2 hours	3 hours	4 hours	5 hours	6 hours	More than 6 hours, please specify

5. Have you ever coached in a rugby team that used, or is currently using, a specific conditioning programme at training sessions to improve players' performance and / or fitness?

☐ No

☐ Yes. Please describe.

____
____
____

6. Have you ever coached in a rugby team that used, or is currently using, a specific conditioning programme at training sessions to reduce players' risk of injury?

☐ No

☐ Yes. Please describe.

____
____
____

SECTION B: Coaches' Beliefs & Attitudes

This section of the survey asks you questions about your attitudes and feelings towards delivering a 20 minute rugby specific balance, agility and strength training programme with your team at every game and training session during the next rugby season.

The questions use a rating scale with 7 places. You need to circle the number that best describes what you think. For example, if you were asked to rate 'The weather in Bristol' and you think it is 'extremely good' then you would circle the number 7, like this:

The weather in Bristol is

Bad	1	2	3	4	5	6	7	**Good**
	Extremely	**Quite**	**Slightly**	**Neither**	**Slightly**	**Quite**	**Extremely**	

Even though some of these questions might seem repetitive, please make sure you answer all the items – don't leave any out.

Only circle one number for each question

Please do not circle between the numbers

1. Completing a 20 minute rugby-specific balance, agility and strength training programme with my team at every game and training session during the rugby season would be (circle one)

Bad	1	2	3	4	5	6	7	**Good**
	Extremely	**Quite**	**Slightly**	**Neither**	**Slightly**	**Quite**	**Extremely**	

2. Completing a 20 minute rugby-specific balance, agility and strength training programme with my team at every game and training session during the rugby season will improve my players' physical skills such as balance, agility and strength (circle one)

Likely	1	2	3	4	5	6	7	
	Extremely	**Quite**	**Slightly**	**Neither**	**Slightly**	**Quite**	**Extremely**	**Unlikely**

3. Decreasing my players' risks of sustaining an injury would be (circle one)

	1	2	3	4	5	6	7	
Bad	**Extremely**	**Quite**	**Slightly**	**Neither**	**Slightly**	**Quite**	**Extremely**	**Good**

4. When it comes to rugby, I want my players to do what I ask them to do (circle one)

	1	2	3	4	5	6	7	
Disagree	**Extremely**	**Quite**	**Slightly**	**Neither**	**Slightly**	**Quite**	**Extremely**	**Agree**

5. Completing a 20 minute rugby-specific balance, agility and strength training programme with my team at every game and training session during the rugby season would be (circle one)

	1	2	3	4	5	6	7	
Pleasant	**Extremely**	**Quite**	**Slightly**	**Neither**	**Slightly**	**Quite**	**Extremely**	**Unpleasant**

6. Completing a 20 minute rugby-specific balance, agility and strength training programme with my team at every game and training session during the rugby season would be boring and repetitive (circle one)

	1	2	3	4	5	6	7	
Unlikely	**Extremely**	**Quite**	**Slightly**	**Neither**	**Slightly**	**Quite**	**Extremely**	**Likely**

7. Improving my players' physical skills such as balance, agility and strength would be

	1	2	3	4	5	6	7	
Bad	**Extremely**	**Quite**	**Slightly**	**Neither**	**Slightly**	**Quite**	**Extremely**	**Good**

8. Completing a 20 minute rugby-specific balance, agility and strength training programme with my team at every game and training session during the rugby season will reduce my players' risk of sustaining an injury (circle one)

	1	2	3	4	5	6	7	
Unlikely	**Extremely**	**Quite**	**Slightly**	**Neither**	**Slightly**	**Quite**	**Extremely**	**Likely**

9. A boring and repetitive rugby specific balance, agility and strength training programme would be (circle one)

Bad	1 Extremely	2 Quite	3 Slightly	4 Neither	5 Slightly	6 Quite	7 Extremely	Good

10. My players think that (circle one)

They should	1 Extremely	2 Quite	3 Slightly	4 Neither	5 Slightly	6 Quite	7 Extremely	Should not

Complete a 20 minute rugby-specific balance, agility and strength training programme with my team at every game and training session during the rugby season.

11. I expect to have fun with my team during the next rugby season (circle one)

Unlikely	1 Extremely	2 Quite	3 Slightly	4 Neither	5 Slightly	6 Quite	7 Extremely	Likely

12. Most rugby teams complete a 20 minute rugby specific balance, agility and strength training programme at every game and training session during the rugby season (circle one)

True	1 Extremely	2 Quite	3 Slightly	4 Neither	5 Slightly	6 Quite	7 Extremely	False

13. My team/ club doctor or physiotherapist thinks that (circle one)

I should	1 Extremely	2 Quite	3 Slightly	4 Neither	5 Slightly	6 Quite	7 Extremely	Should not

Complete a 20 minute rugby-specific balance, agility and strength training programme with my team at every game and training session during the rugby season.

14. I intend to deliver a 20 minute rugby-specific balance, agility and strength training programme with my team at every game and training session during the rugby season (circle one).

Unlikely	1 Extremely	2 Quite	3 Slightly	4 Neither	5 Slightly	6 Quite	7 Extremely	Likely

15. When it comes to rugby, I want to do what my team/ club doctor or physiotherapist thinks I should do (circle one)

1	2	3	4	5	6	7
Extremely	**Quite**	**Slightly**	**Neither**	**Slightly**	**Quite**	**Extremely**

Disagree **Agree**

16. When it comes to rugby, how much do you want your team to be like other rugby teams (circle one)

1	2	3	4	5	6	7
Extremely	**Quite**	**Slightly**	**Neither**	**Slightly**	**Quite**	**Extremely**

Very much **not at all**

17. Most high level rugby players complete a 20 minute rugby specific balance, agility and strength training programme at every game and training session during the rugby season (circle one)

1	2	3	4	5	6	7
Extremely	**Quite**	**Slightly**	**Neither**	**Slightly**	**Quite**	**Extremely**

True **False**

18. When it comes to rugby, how much do you want your players to be like other high level players (circle one)

1	2	3	4	5	6	7
Extremely	**Quite**	**Slightly**	**Neither**	**Slightly**	**Quite**	**Extremely**

Very much **not at all**

19. Having fun with my team will enable me to complete a 20 minute rugby specific balance, agility and strength training programme at every game and training session during the rugby season (circle one)

1	2	3	4	5	6	7
Extremely	**Quite**	**Slightly**	**Neither**	**Slightly**	**Quite**	**Extremely**

Disagree **Agree**

20. I expect my players will sustain an injury sometime during the next rugby season (circle one)

1	2	3	4	5	6	7
Extremely	**Quite**	**Slightly**	**Neither**	**Slightly**	**Quite**	**Extremely**

Unlikely **Likely**

21. I anticipate that my players will complete a 20 minute rugby specific balance, agility and strength training programme at every game and training session during the rugby season (circle one)

1	2	3	4	5	6	7
Extremely	**Quite**	**Slightly**	**Neither**	**Slightly**	**Quite**	**Extremely**

Disagree **Agree**

22. Sustaining an injury will enable my players to complete a 20 minute rugby specific balance, agility and strength training programme at every game and training session during the rugby season (circle one)

1	2	3	4	5	6	7
Extremely	**Quite**	**Slightly**	**Neither**	**Slightly**	**Quite**	**Extremely**

Disagree **Agree**

SECTION C: Coaches' Knowledge of Injury Risk and Prevention

1. In your opinion what is the most common body region injured among rugby players in general? Indicate <u>one</u> only

☐ Head & face ☐ Pelvis and hips ☐ Hamstrings and thighs
☐ Chest & abdomen ☐ Shins and calves ☐ Feet and hands
☐ Shoulder and arms ☐ Knees and ankles ☐ other, please specify___________________________________

2. What are some of the factors that you think may contribute to a rugby players' risk of sustaining and injury?

☐ Inadequate warm-up ☐ Lack of fitness or training ☐ Body contact
☐ Lack of stretching/ flexibility ☐ Player's genetic background ☐ Lack of skill/ poor technique
☐ Poor muscle strength ☐ Aggression/ tackling risk ☐ other, please specify ______________________

3. Do you believe some rugby injuries are preventable?

☐ No…Please explain your answer -

____
____
____

☐ Yes…which injuries and what are some of the factors that you think may help prevent rugby players' risk of sustaining an injury?

Preventable injury	How it could be prevented
1.	1.
2.	2.
3.	3.
4.	4.

☐ Don't know…please explain your answer-

____

____

____

4. Who do you think are the people responsible for preventing a rugby players' risk of sustaining an injury? (tick up to 3 most important answers)

☐ Coaching staff
☐ Doctors
☐ Other…please specify ____________________
☐ Parents
☐ Physiotherapists
☐ Rugby Administrators
☐ other medical professionals
☐ Players
☐ Referee

5. What are some of things that you could do (or neglect to do) as a coach that may contribute to your players' risk of sustaining an injury? (tick up to 3 most important answers)

☐ Ensure they are fit
☐ Stretch muscles
☐ Ensure adequate recovery /rest
☐ Eat healthy
☐ Complete a proper warm up
☐ avoid taking risk
☐ Focus on technique
☐ other … please specify __________________
☐ Strengthen muscles

SECTION D: Coaches' feedback on the 11+ or shoulder focused warm up programme

1. How did you learn about the 11+ or shoulder focused warm up programme?

☐ I've never heard about it
☐ From participation in this research study
☐ From another source, please describe:_____________________________________

2. Have you ever visited the 11+ or shoulder focused warm up programme website?

☐ Yes, only once
☐ No, never
☐ Yes a few times
if no, please describe your reason:

____

3. On average, how many times a week did your team complete the 11+ or shoulder focused warm up programme during the 2016 season before games and practices?

☐ We never did the programme ☐ Approximately 2-3 times a week

☐ Less than once a week ☐ more than 3 times a week
☐ Approximately once a week

4. What are some of the things you did not like about doing the 11+ or shoulder focused warm up programme with your team during the 2016 season before games and training? (tick as many as appropriate)

☐ We never did the 11+ or shoulder focused warm up programme
☐ the exercises were too easy
☐ Nothing, I really enjoyed the 11+ or shoulder focused programme
☐ The exercises were boring
☐ I didn't understand the reason for the exercises ☐ the exercises are not specific enough
☐ We had limited time to practice other rugby skills ☐ Other, please describe briefly________
☐ The exercise were too hard

____

5. What are some of the things you did like about doing the 11+ or shoulder focused warm up programme with your team during the 2016 season before games and training? (tick as many as appropriate)

☐ We never did the 11+ or shoulder focused warm up programme
☐ Nothing, I really hated doing the 11+or shoulder focused programme
☐ Learning about some exercises that might decrease my chances of injury
☐ Doing some exercises that are different to usual rugby practice
☐ Doing a set of warm up with the same exercises in order each time
☐ Feeling like I was getting better at doing the exercises
☐ The challenge of doing the exercises
☐ Getting an advantage over other rugby teams
☐ Other reasons, please describe briefly____

6. Is there any other comments or suggestions you would like to make about the 11+or shoulder focused warm up programme?

____
____
____
____

Thank you for your time in doing this survey

Appendix E: Participant information and informed consent (Chapter 7)

The effect of a lycra compression sleeve on shoulders function in rugby union players.

Player information and consent form

Principle Investigator: Mr Vincent Singh

Other investigators: Katie Kinnear, Natasha Ryan, Bryony Lynes, Vivien Bradley, Tosca Little.

We would like to invite you to participate in this study to evaluate the effect of wearing a lycra compression sleeve on rugby union players' shoulder function. The following information outlines why we are doing the study and how it will affect you. Please take your time to read the information carefully and if there is anything that you do not understand please speak to the people responsible for your team (coach/trainer). You are also welcome to contact the researchers directly for any further information. Once you have read and understood the information, and if you wish to be in the study, you will need to sign and return the Player Consent Form.

Background to the study

Optimal shoulder function is vital to performance in rugby. The game requires the use of the shoulder in defensive play, for example in tackling opponents using good technique. To cope with this demand, it is thought that the shoulder joint and surrounding region need to have good mobility with a high degree of strength and stability.

Research has shown that there is an association between shoulder instability and the risk of shoulder injury in rugby players. We are investigating what effect wearing a lycra compression sleeve can have on shoulder function to help us better understand how we may try to prevent these injuries.

What does the study involve?

In February - March 2017 you are invited to book in with us and be tested on the following measurements related to your shoulder function. Each round of testing is expected to last 30 - 45 minutes per player and will comprise of the following tests which will be carried out twice:

1. Participant demographics: age, general health, history of previous shoulder injury, on-field playing position and dominant side.
2. Anthropometrics: height and weight
3. Shoulder Function question
4. Clinical evaluation: active and passive shoulder range of motion and strength (internal and external rotation), stability and laxity tests and diagnostic ultrasound scan of the shoulder.
5. Functional test: Upper Limb Y Balance test

During the testing session you will be initially tested without a lycra compression sleeve, following this baseline testing you will then be fitted with a lycra compression sleeve according to your specific measurements as described by the manufacturers and we ask that wear the garment for 30 minutes and then return to be retested with the garment on. Following baseline testing, all players will be appropriately fitted with a lycra compression sleeve to wear for 1 weeks, 7 hours a day. Players will be asked to complete a diary recording when and how long the compression sleeve is worn during the study. After the week intervention period, the shoulder testing protocol will be repeated. This information will then be analysed by researchers at the University of the West of England and the University of Bath.

Who are we asking to participate?
All rugby players in the rugby union squads in a sample of universities in England.

Do I have to take part?
No, it is not compulsory to participate. It is up to you to decide whether you would like to take part. If you decide to participate, you will need to sign a consent form that confirms you have read this information and you agree to participate in the study. You may withdraw from the study at any time and without a reason by contacting us.

What do I have to do?
In January 2017, we will invite all participants to book an appointment to be tested on the abovementioned shoulder tests with and without the compression sleeve in the university Human Analysis Laboratory (UWE) or Applied Biomechanics Suite (University of Bath). The research team will explain the tests to you and allow you an opportunity to ask questions and familiarise yourself with the testing procedures. Following baseline testing, all players will be appropriately fitted with a lycra compression sleeve to wear for 1 weeks, 7 hours a day. Players will be asked to complete a diary recording when and how long the compression sleeve is worn during the study. After the week intervention period, you will be need to book an appointment to be retested on the shoulder testing protocol.

Are there any risks from taking part?
You will undertake a series of simple functional shoulder screening tests which will carry minimal risk of injury. Delayed onset muscle soreness may result from doing the testing however every effort will be made to reduce the likelihood of this occurring.

Will information about me be kept confidential?
We will follow the regulations set out in the Data Protection Act, which means that we must have your permission to collect information about you during the course of this study. All collected information will be anonymised and stored using a code number rather than your name. Your identity will be protected in any reports produced from the results.

What will happen to the information of the study?
Researchers at the University of the West of England and the University of Bath will analyse the information and produce a report. The report will describe the effects of wearing a lycra compression sleeve on shoulder function in rugby union players. No personal references will be made in any report.

Enquiries:
Should you have any further queries about this study, please contact Vincent Singh (tel: 078 94129702; v.singh@bath.ac.uk Department of Health, University of Bath).

The effect of a lycra compression sleeve on shoulder function in rugby union players.

Player information and consent form

I have read and understood the information about this study and I have had a chance to ask questions.

I agree to take part in the study and give consent for researchers to carry out shoulder function tests and to wear the lycra compression sleeve. I agree that the information will only be used for research purposes and in a report to my club.

I understand that I can withdraw from this study at any time without being asked why.

Participant:

Name	Date	Signature

Researcher taking consent:

Name	Date	Signature

OFFICE USE ONLY	
University	
PLAYER PROJECT ID	
PLAYERS SEASON ID	

In the event that you longer wish to participate in the study, please tick one of the boxes below:

I am happy for any data collected from me to be used by the researchers	
I am not happy for any data collected from me to be used by the researchers	

Appendix F: Stanmore Percentage of Normal Shoulder Assessment (Chapter 7)

“A normal shoulder is one which is pain--free, with a full range of movement, normal strength and stability, and allows you to do what you feel your shoulder, if normal, should allow you to do. A normal shoulder is scored as 100 percent, while a completely useless shoulder is scored as 0 percent. Overall where would you rate your shoulder between 0 and 100 percent, at this present time?”