# Exploring the Efficacy of a Lumbo-Pelvic-Hip Injury Reduction Strategy in Professional Rugby Union

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## DECLARATION SHEET

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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Date ........07.04.2019..............................................................

**STATEMENT 1**

This thesis is the result of my own investigations, except where otherwise stated. Where correction services have been used the extent and nature of the correction is clearly marked in a footnote(s). Other sources are acknowledged by footnotes giving explicit references. A bibliography is appended.

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## Abstract

**Objectives:** The aim of this study was to implement a complete sequence of prevention (Van Mechelen, et al 1987) to reduce lumbo-pelvic-hip (LPH) injuries in a professional men's rugby union team and examine its effectiveness. A secondary aim was to examine, on completion of the tailored program, the players' perceptions of injury reduction programmes. **Design:** Insider action research using an ecological mixed methods design. **Methods:** In season 1 baseline injury surveillance data was collected to establish the extent of the LPH injury problem. In season 2 and 3, a pre-season screening battery of hip and groin strength measures were administered pre and post the completion of a Yo-Yo IR1 test. Based on the change scores of the strength measures, the players were prescribed a tailored preventative exercise program that was followed during their lower limb strength sessions throughout the season. As part of the end of season 2 review, players were anonymously questioned on injury reduction programmes and their implementation. Injury surveillance data was prospectively recorded throughout. **Results:** The use of a tailored injury reduction programme aimed at reducing LPH injuries in professional rugby union successfully reduced total severity of injuries (936d v 417d in season 3). Average severity was significantly reduced across the three seasons (78d v 12.6d in season 3). Prevalence also reduced (21% v 13% in season 3) when compared to the baseline season 1. Players reported that they are confident in their ability to engage with injury reduction programmes providing it was individualised, written by the medical team/strength and conditioning staff in conjunction with the players themselves and performed under supervision by the medical team. **Conclusions:** A tailored LPH injury reduction programme can reduce total severity, average severity and prevalence of LPH injuries. Players' reported that injury reduction programmes are socially appropriate, important and expected in an elite environment. Insider action research should be considered when looking to implement injury prevention research in the real world setting.

**Key Words:** Injury reduction, hip, groin, injury surveillance, players' perceptions rugby union

While the individual man is an insoluble puzzle, in the aggregate he becomes a mathematical certainty.
You can, for example, never for foretell what any one man will do, but you can say with precision what an average number will be up to.
Individuals vary, but the percentages remain constant.
So says the statistician.

Arthur Conan Doyle/Sherlock Holmes, (1890)

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## Table of Abbreviations

| | |
|---|---|
| AB | Adductor Brevis |
| ABD | Abduction |
| ACC | Accident Compensation Corporation |
| ACL | Anterior Cruciate Ligament |
| ACSM | American College of Sports Medicine |
| ADD | Adduction |
| AFL | Australian Rules Football (governing body) |
| AL | Adductor Longus |
| ARGP | Adductor Related Groin Pain |
| BFM | Biceps Femoris Muscle |
| BKFO | Bent Knee Fall-out (test) |
| CERT | Consensus on Exercise Reporting Template |
| CVD | Cardiovascular Disease |
| EBP | Evidence Based Practice |
| EL | Each Leg |
| EMG | Electromyography |
| ER | External Rotation |
| FABER | Flexion-abduction-external rotation (test) |
| FAIR | Flexion-adduction-internal rotation (test) |
| FIFA 11+ | Federation Internationale de Football Association 11+ |
| FLXN | Flexion |
| FMS | Functional Movement Screen$^{TM}$ |
| G | Gracilis |
| GPS | Global Positioning System |
| HHD | Hand Held Dynamometer |
| HQS | High Quality Study |
| IAR | Insider Action Research/ Insider Action Researcher |
| ICC | Intra-class Correlation Coefficient |
| ILL | Ilioinguinal Ligament |
| IR | Internal Rotation |
| IR-1 | Intermittent Recovery Test Level 1 |
| LPH | Lumbo-Pelvic-Hip |
| LQS | Low Quality Study |
| MeSH | Medical Subject Headings |
| NHE | Nordic Hamstring Exercise |
| OCEBM | Oxford Centre of Evidence-based Medicine |
| P | Pectineus |
| PEP | Prevent Injury and Enhance Performance (programme) |
| PRISMA | The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (guidelines) |
| PS | Pubic Symphysis |

| | |
|---|---|
| RA | Rectus Abdominis |
| ROM | Range of Movement |
| SB | Swiss Ball |
| SDT | Self Determination Theory |
| SRGP | Sports Related Groin Pain |
| STL | Sacrotuberous Ligament |
| TBP | Theory of Planned Behaviour |
| TIP | Team-sport Injury Prevention (cycle) |
| TRIPP | Translating Research into Injury Prevention Practice |
| WHO | World Health Organisation |

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# 1.0 Introduction

The aim of the following chapter is to introduce the author in the context of this study and to highlight the complex areas surrounding sports injury prevention research and implementation. This will include a discussion of the concept of sports injury risk and associated factors. A brief historical overview of the theoretical framework for injury prevention and current examples of sport's injury prevention programmes will also be appraised. The chapter will then introduce the complexities of the anatomical region that is the lumbar spine, hip and groin and highlight the overlapping and concurrent regional anatomy. Diagnostic terminology in the past has been confused, descriptive and often non-pathological. The current consensus on diagnostic terminology will be presented and finally the overall incidence of lumbar-pelvic-hip injuries in sport, and specifically rugby union will be presented.

## 1.1 Motivation for the Study

As a Graduate Sports Therapist, the first of the five pillars of competency required for professional body membership and thus a license to practice is 'injury prevention' (Society of Sports Therapists, 2019). I have worked as a Graduate Sports Therapist for almost 20 seasons in semi-Professional, Professional and International sport, and from 2008-2018 I worked as 'Head of Rehabilitation' for one of the four senior men's professional Welsh Rugby Regions. In this role I led the sports trauma management of injuries at all games and the injury prevention strategy for the region. The role also involved leading on the rehabilitation and 'return to playing well' of any player predicted to be out for more than six weeks or any post-surgical player. I would lead a multidisciplinary team in the injury management on field, the rehabilitation and the return to play decision making that would take a player from acutely injured to discharged and the subsequent ongoing re-injury preventative care.

My clinical philosophy has always surrounded three key areas. Firstly, that no player should sustain a 'preventable injury' and therefore suffer needlessly. Secondly, that every player should be afforded the opportunity to play at the highest level and develop a long and prosperous career in the sport of rugby union. Finally, that players should be able to transition out of rugby union, in to other occupational roles, at a time of their choosing.

I see myself as a practitioner researcher, grounded in the professional sporting workplace, but with a responsibility to critically examine the effectiveness of the work I do and to disseminate the key findings. I also feel that within the practitioner research field of high performance sport, the player/patient voice is often overlooked. There is an arrogance amongst high performance sports staff that they ‘know best’ and simply overlook the important role the player assumes in this process. They are not ignorant passengers – they are often more aware of the high performance environment than we give them credit and they should be viewed as important stakeholders in any intervention.

The region in question is the poor relation of Welsh, Anglo-Welsh, Celtic and European Rugby, with the smallest high performance budget and player wage bill (typically £4.5 million), when compared to a notional cap of €8.6million in French club rugby (Gallagher, 2011). That said, the team have always been the ‘plucky underdogs’ who are competitive, for example, regularly reaching the final stages of European Cup Competitions. The limited budget meant that the squad was characterised by 3 key sub-groups. The first group of players were young and untested in the professional environment – often products of the regions’ own academy. The region holds the record for the youngest player to make their professional senior rugby debut (at 16 years 313 days), beating its own previous record of 17years and 28 days. With the younger players, I would also assume the role of ‘in loco parentis’ during training, games and away trips. The second group would include world-class players signed by the region on a ‘cheap’ contract due to existing or previous injury history. These were players no-one else would sign, who were looking for a place to heal and regain form. The medical team’s job would be to fix them, get them back playing to their near-best and then they would usually be signed for a more appropriate salary with a bigger club. My role was to put them back together – even if their injury was so severe or conflicted by a complex injury history that it seemed unlikely. As a team of medical staff, we had to be innovative, providing novel solutions to significant problems other medical teams could not or would not fix. The final group of players were experienced ‘old heads’ coming towards the end of their careers, looking for a place to see out their professional rugby life and prepare for a transition in to retirement. These players also had their unique challenges. They had significant injury histories and degenerative pathologies that required a substantial management. Too little exposure to load and they would get injured, too much and you would exacerbate an existing injury. We certainly were a unique population, one that was at a significantly increased risk of sustaining injuries. For the younger players, new to the professional environment, research shows us that sudden spikes in training and competition loads, especially in athletes unaccustomed to full-time training, increase injury risk (Gabbett, 2016). Academy players would typically complete less than six to eight sessions per week including a game. Senior players would complete 16 sessions per week plus a game. This academy to senior rugby transition needed to be managed. From the epidemiology literature, previous injury is frequently cited as a predictor of future injury risk (Hägglund et al, 2006). Players in sub-group two and three both typically had significant histories that placed them at an increased risk of future injury.

After the initial few seasons of finding my feet, the role of injury prevention became central to my motivation for working. We would share our experiences and disseminate our findings with other professionals and it quickly became clear that we were doing something no one else was doing, or something that no one else was willing to talk about! The small size of our medical department meant that I was in a unique position. I was the person to prospectively record the number of injuries sustained and look for patterns. I would witness the trauma of the injury from the second it happened on field and see the process through to its end. I would meet the player in the emergency department post-match and sit with them until a clear diagnosis and management strategy would be confirmed. Sometimes I went into theatre to watch the surgical repair take place. I would then work with these players daily in their rehabilitation and attend follow-up appointments. As a 'Talented Athlete Lifestyle Support' officer, I would also listen to them discuss the psychological impact of the injury on their professional and home life. The consequences of a sports injury to a professional athlete can be devastating. Sometimes career ending. Sometimes life changing. Especially for the young player who is at the start of their career, with grand plans of being an International or British and Irish Lion. The player welfare role of sports injury prevention cannot be underestimated. The players I have worked with were my motivation for this project. I wanted to do my very best to ensure that wherever possible, no player would sustain a preventable injury or suffer needlessly. I wanted to ensure that players had every opportunity to perform at the highest level and enjoy a long and prosperous career. It was also important to me that players were able to transition out of rugby when the time was right for them and that a professional rugby career left them still fit and healthy enough to carry out activities of daily living e.g. play with their children and fulfil other occupational roles.

## 1.2 Introduction to Sport Injury Risk

Injury prevention is a broad term used to describe any intervention aimed at reducing the injury burden in a specific population. Examples of injury prevention *methods* involve educational strategies targeting the coaches, officials, parents and/or players e.g. on contact or tackle technique; changes to sporting policy e.g. game constraints such as league structure, game time or pitch dimensions for specific age groups; changes to rules and laws e.g. height of the tackle in rugby union and red/yellow card sanctions for violations and finally, changes to safety equipment e.g. the use of helmets or other protective equipment such as mouth-guards or padding. The introduction of corrective exercises to attenuate physical traits associated with increased risk of injury is termed ‘prehabilitation’ or preventative exercise and is another form of injury prevention method.

Preventing sports injuries is the utopia of sports medicine. The concept is simple; the clinician performs a periodic health examination to screen for risk factors of injury that can be easily corrected through a targeted intervention programme designed to mitigate the injury risk. It is that simple. Examples of screening programmes following this concept exist throughout medicine. For example, despite being apparently healthy and free from disease a General Practitioner may decide that, given your age, gender, ethnicity, height, weight, blood pressure and/or cholesterol levels, you are at an increased risk of cardiovascular disease (CVD) and prophylactically prescribe you statins. Clinicians looking to reduce the sports injury risk typically follow Van Mechelen’s (1987) sequence of prevention. This simple four step process requires the clinician to establish the extent of the sports injury problem – based upon identifying the most common and costly injuries. It is then necessary for the clinician to understand and screen for the risk factors and injury mechanisms that play a part in the injury occurrence. From here the clinician can develop a targeted prevention programme, apply it to those players deemed ‘at risk’ and monitor its effectiveness. Despite the conceptual simplicity of this approach, to date, there is no screening test battery available to predict sports injuries with adequate test properties and no intervention study providing evidence in support of screening for injury risk.

Recently, researchers have questioned the efficacy of screening for injury prevention. Bahr (2016) highlights just how unrealistic it is to identify which athletes will and will not get injured using current risk factor screening tests. He states that while a statistically significant *association* between a specific test result and injury risk indicates that there may be a *causal relationship*, it is not sufficient to use the test to predict who is at risk of injury. Markers proposed for classifying or predicting risk in individuals must be held to a much higher standard than merely being associated with outcome and this is where the literature is lacking. Further to this Clarsen and Berge (2016) state that identifying who will get injured (and who will not) based on risk factor testing is wishful thinking for the foreseeable future.

The main issue here is that of risk. By definition screening is a strategy to identify an unrecognised disease in individuals with or without symptoms (Stevenson, 2010). However in sport, screening seeks only to establish risk factors for injury, rather than the injury itself. It identifies players who possess exposures or traits that increase their likelihood of sustaining an injury. Even if these have been identified it does not guarantee or predict the player will sustain an injury, equally if the deficiencies and risk factors are absent or they have been detected and addressed it does not guarantee the player will remain injury free. Sports injuries are dynamic, complex and multifaceted and given the right combination of external factors, such as force and direction of a tackle, injuries will still occur – such is the nature of sport. It is also acknowledged that risk factors are temporal and can vary over time (Verhagen et al, 2018). Screening offers a static screenshot of risk factors and should be repeated regularly – repeating measures and monitoring variables over time.

Once a player is screened, the next step is to introduce preventative measures. Rose (1981) proposed the ‘prevention paradox’. He states that a measure that brings large benefits to the population/community offers little to each participating individual. The preventative strategy that concentrates on high-risk individuals may be appropriate for those individuals, as well as being a wise and efficient use of limited medical resources; but its ability to reduce the burden of disease in the whole community tends to be disappointingly small. Potentially far more effective is the mass strategy, whose aim is to shift the whole population's distribution of the risk variable. In sports injury terms, players with low to moderate risk sustain the majority of sports injuries by sheer volume – there are more players at moderate to low risk than high risk in any given population and therefore as a group, they sustain the most number of injuries. An intervention aimed at this group would produce the greatest effect on the overall injury burden, compared to an intervention aimed at the small number of high risk players who sustain the minority of sports injuries. The paradox is that a universal prevention approach in a low-risk population will, in absolute terms, benefit more athletes than a targeted approach in high-risk individuals. Whether a prevention strategy is targeted ‘en masse’, or tailored to specific individuals depends on the clinicians’ preference, the medical resources and time available with the players.

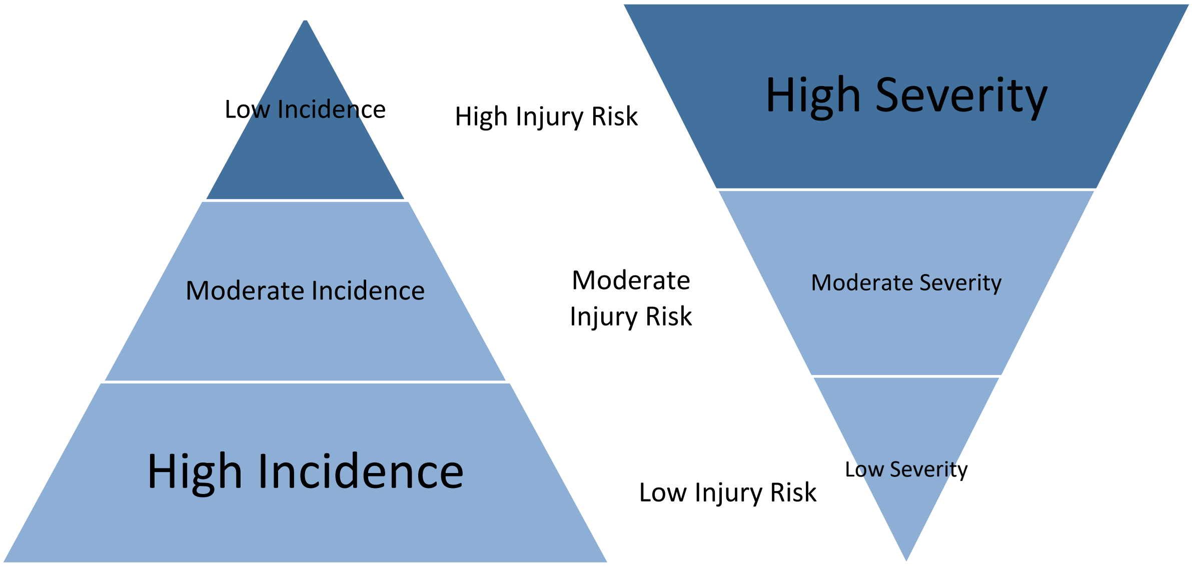



Figure 1.0 Generic example of the numbers of injuries sustained (incidence) by participants of differing risk of injury, and the subsequent severity of injury sustained by each group.

This study seeks to reduce the burden of injuries to a specific area (lumbo-pelvic-hip) in a specific population (one professional rugby union team) using a tailored injury reduction programme and examine the players' perceptions of the intervention. It is universally acknowledged that such an intervention will not prevent all injuries to this team of players. It is simply an application of Van Mechelen's 4-step sequence of prevention in a real life setting. In this regard, this study series is unique in that it attempts to reduce a specific injury problem in a professional rugby union club setting using a targeted screen and intervention programme. To our knowledge, this has not been done before.

## 1.3 Factors Associated with Sports Injury Risk

Aetiology is the study of causes. Sports injuries are multi-risk phenomena with various risk factors interacting at a given time (Meeuwisse, 1994). Factors associated with injury proneness can be classified into extrinsic and intrinsic risk factors. Table 1.0 highlights the common intrinsic and extrinsic risk factors for sports injuries. Intrinsic risk factors *pre-dispose* the athlete to injury and include factors such as age, sex and physical condition.  These are important determinants of load tolerance, for example, the mechanical properties and size of a ligament are influenced by age, sex, body size and training background (Bahr and Krosshaug, 2005). Intrinsic risk factors may be minimised as the athlete participates and adapts to a graded exposure of the competitive environment. Injury prevention strategies aimed at reducing intrinsic risk factors often seek to address deficiencies in physical fitness, joint mobility, muscle tightness/weakness, motor abilities and sports specific skills proficiency. Exposure to extrinsic risk factors (such as type of sport, amount of training, training environment and equipment) make a pre-disposed athlete *susceptible* to injury.  For example, an athlete with low bone density is pre-disposed to stress fractures, however they are not susceptible to stress fractures until they are exposed to a sharp increase training load on a hard surface (e.g. road running), with inadequate recovery between sessions.

Table 1.0 Extrinsic and intrinsic risk factors for sports injuries (van Mechelen, 1992; Taimela et al, 1990; Lysens et al, 1991).

| **Extrinsic Risk Factors** | **Intrinsic Risk Factors** |
|---|---|
| *Exposure:* | *Physical characteristics:* |
| Types of sport | Age |
| Exposure time | Gender |
| Playing position | Somatotype |
| Level of competition | Previous injury history |
| *Training:* | Physical fitness |
| Type | Joint mobility |
| Amount | Muscle tightness/weakness |
| Frequency | Ligamentous instability |
| Intensity | Anatomical abnormalities |
| | Motor abilities/ co-ordination |
| | Sport-specific skills/technical proficiency |
| *Environment:* | *Psychological profile:* |
| Type of playing surface | Motivation |
| Indoor/outdoor | Risk taking |
| Weather conditions | Stress coping |
| Time of season | |
| Human factors (team mates, opponents, referee, coach, spectators) | |
| *Equipment:* | |
| Protective equipment | |
| Playing equipment | |
| Footwear, clothing | |

## 1.4 Theoretical Frameworks for Injury Prevention

The most widely cited model of sports injury prevention is the four-step 'Sequence of Injury Prevention' model (van Mechelen et al, 1992). This model is based on the principle that injuries are preventable, and also that to maximise the chance of preventing injury, robust surveillance should be in place to inform and evaluate prevention strategies.

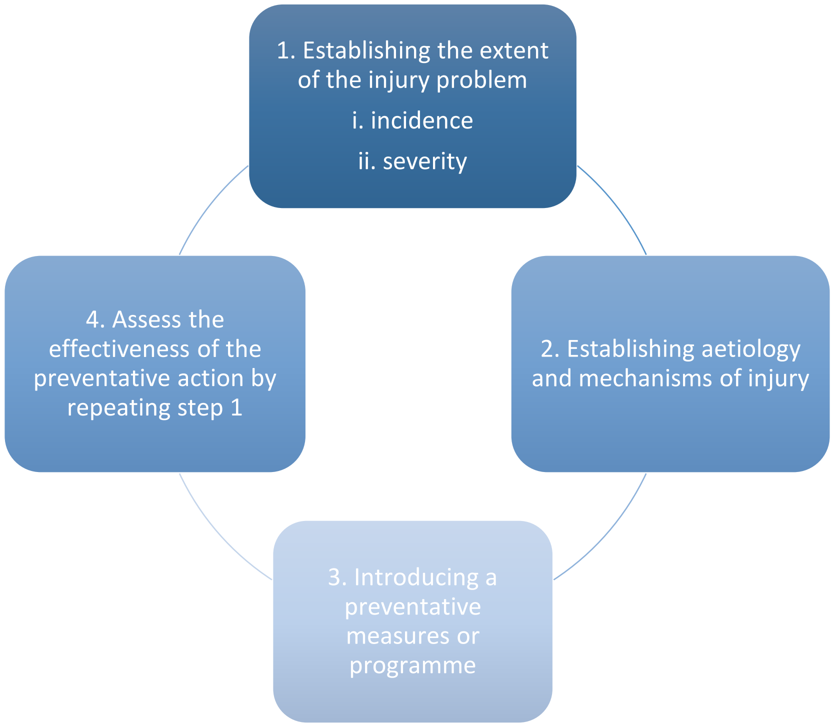



Figure 1.1 The sequence of prevention of sports injuries (van Mechelen et al, 1987).

In 1994, Meeuwisse published a multifactorial model of causation based upon a modification of work completed in infectious disease (Figure 1.2). The model attempted to account for the interaction of multiple risk factors, both internal (intrinsic) and external (extrinsic). It highlighted the importance of examining intrinsic pre-disposing factors as well as those extrinsic factors that interact to make the athlete pre-disposed to injury before the injury-inciting event occurs.

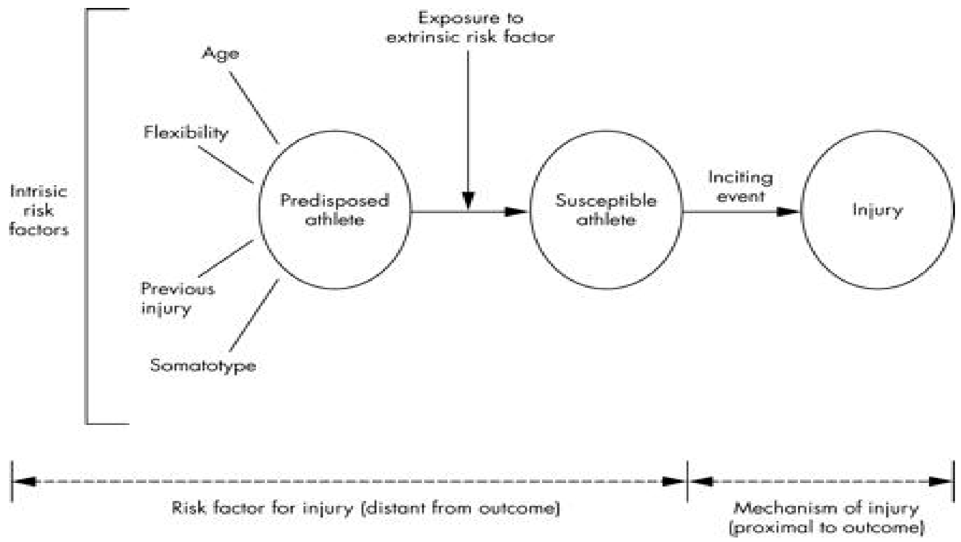



Figure 1.2 Previous multifactorial model of athletic injury aetiology (Meeuwisse, 1994).

Bahr and Krosshaug (2005) elaborated on the characteristics of the inciting event as a component of the causal pathway. The importance of the playing situation and the player/opponent behaviour in addition to the global and detailed biomechanical description of the inciting event were highlighted as important in the injury causal pathway.

The criticisms of this model generally surrounded its linearity – if you were an athlete with one or more predisposing factors who was subsequently exposed to an extrinsic risk factor, you then became a susceptible athlete. Presented with an inciting event, such as a tackle, you would become injured. This model has a definitive start and end point. If this model were true, we would expect to see far higher injury incidences in sports and exercise participants. This model in its current form also did not explain how athletes with predisposing risk factors, exposed to extrinsic risk factors and inciting events, avoided injury.

As a response to some of the criticisms made of the multifactorial model of athletic injury, Meeuwisse et al presented a dynamic model of aetiology in sports injury in 2007 (Figure 1.3). They acknowledged their initial model was too linear – with events following each other sequentially from a beginning to an end point. Although the linear paradigm is common in classical cohort studies, for example in disease research where a finite end point is reached (e.g. death) – the nature of the sports injury is different. A player with intrinsic risk factors may be exposed to extrinsic risk factors repeatedly through multiple participations but not suffer a sports injury – they may even adapt to the exposed extrinsic risk factors to increase their tolerance and reduce their risk of injury. Moreover, injuries may or may not occur under similar conditions. Even if an injury is sustained, it may not necessarily represent a finite end point whereby the individual is permanently removed from participation. The previous model does not account for what happens after injury where the healthy/fit individual returns to sport (Gissane et al, 2001). For example, the rugby player is at an increased risk of anterior shoulder dislocation if he/she has a history of shoulder dislocations, laxity/hypermobility at the glenohumeral joint and strength deficits of the rotator cuff muscle group. This player may or may not be exposed to an inciting event that would cause injury. If they were unlucky enough to sustain an injury – with appropriate surgery and/or rehabilitation they may return to rugby participation.

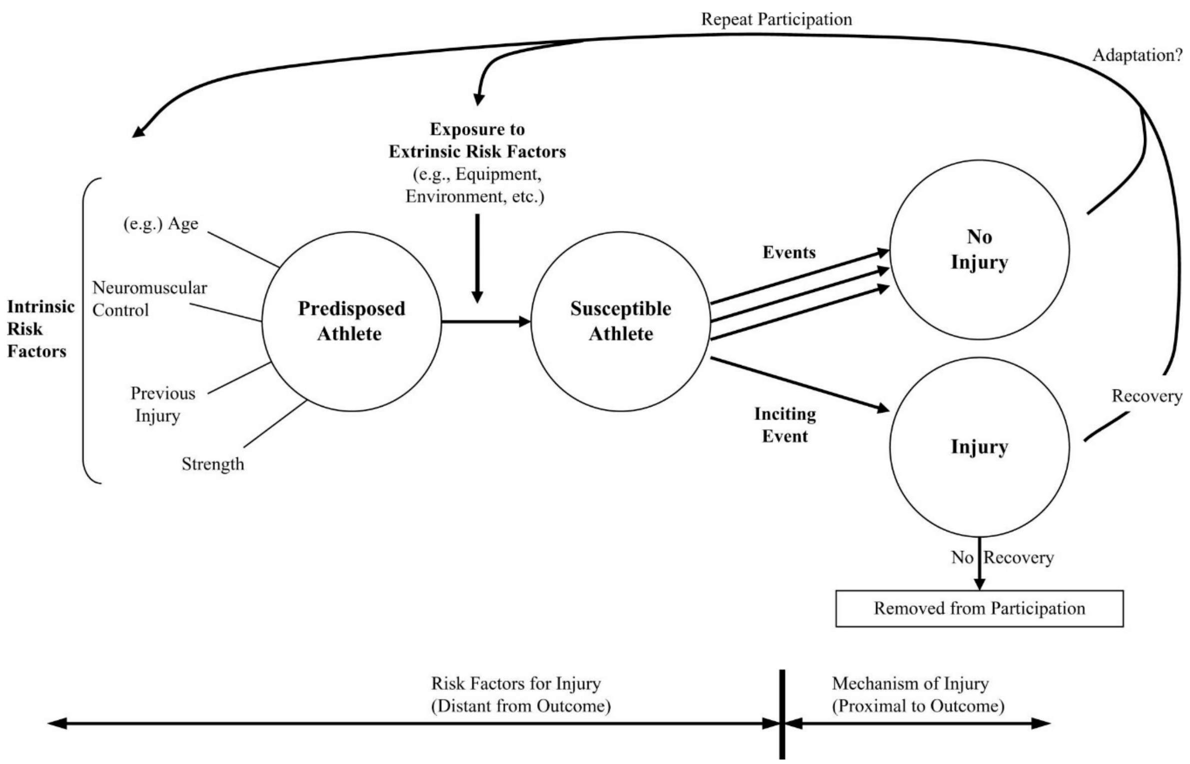



Figure 1.3 A dynamic, recursive model of aetiology in sports injury (Meeuwisse et al, 2007).

Due to the cyclic nature of the dynamic, recursive model, a player can enter the injury chain at any point. A player may present with a unique set of intrinsic predisposing factors that combine with extrinsic risk factors to make the athlete susceptible to injury. The player is then exposed to events, which may or may not result in injury. Where no injury occurs the player may experience some form of adaptation that may then affect the players' intrinsic and extrinsic risk factors and thus alter the players' susceptibility to the future risk of a sports related injury.

More recently, the Translating Research into Injury Prevention Practice (TRIPP) framework has been proposed with a focus on the premise that the success of prevention strategies rests on whether they can be effectively implemented in the real world (Finch, 2006). This model proposes 6 steps:

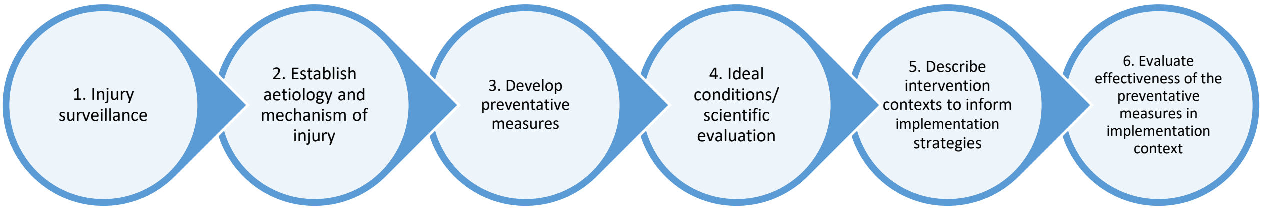



Figure 1.4 The Translating Research in to Injury Preventative Practice (TRIPP) framework for research leading to real-world sports injury prevention.

This model is an extension to the Van Mechelen Sequence of Prevention. Stage 4 (ideal conditions/ scientific evaluation) offers some alternative perspectives on injury prevention research. It is clear from this model that sports injury prevention falls down at the point of implementation. Firstly Finch highlights the *context* of common injury prevention research. This research often occurs under laboratory conditions, with small participant numbers or small groups in a clinical setting. Studies are completed in artificial environments. Where controlled field-based or randomised controlled designs are used, these are performed in the 'ideal setting'. The study provides the teams/cohorts with staff and other resources (e.g. equipment) and often ongoing participation is incentivised. It is generally the case that none of these influences or resources are available to clubs or players after the study has finished.

Very few sports teams have the money, resources, infrastructure or manpower to maintain the same level of activity. This is where sports injury prevention falls down. The research must be sustainable for it to translate in to the ‘real-world’ setting and make meaningful and impactful change to clinical practice.

Very few areas of sports injury prevention research have translated in to practice. One such example is in hamstring strain injury prevention. Hamstring strain injury is the most common cause of lost training and playing time in running-based sports (Bourne et al, 2018). Nordic eccentric strength is easily assessed via a novel testing device (Nordbord$^{TM}$) which is relatively inexpensive when compared to other forms of testing such as isokinetic dynamometry. This testing device assesses a frequently used exercise (Nordic hamstring exercise) and is able to measure peak Nordic eccentric strength in the right and left ankle through a load cell located in each ankle restraint. It will also calculate any asymmetry between the right and left leg. Nordic eccentric hamstring weakness and asymmetry is associated with increased hamstring injuries (Bourne et al, 2015). The Nordic hamstring exercise (NHE) has been proposed as a simple and cost effective injury reduction strategy for hamstring injury. Studies have shown that a low dose (4 sets of 6 repetitions) of NHE performed twice a week over a six week period is sufficient to change muscle strength and architecture (Presland et al, 2018). Large-scale interventions employing the NHE have reported 50–70% reductions in hamstring injuries in sub-elite soccer when athletes are compliant (Arnason et al 2008; Petersen et al, 2011; Seagrave et al, 2014; van der Horst et al, 2015). In rugby union, Evans and Williams (2017) found that adding 3 sets of 3-6 reps of the Nordic hamstring exercise once a week to professional rugby players normal posterior chain strengthening programme increased Nordic eccentric strength during the season (from 391.68 ± 89.1N in June to 471.77 ± 96.3N in March), significantly reduced asymmetry (from 7.5 ± 8.8% in June to 0.01 ± 0.17% in March) and also reduced the incidence of match injuries from 5.2/1000hours to 2.63/1000 hours and reduced total severity from 124d to 99days lost.

More recently, Hanson et al (2014) highlighted several issues with injury prevention research. In particular, they propose three gaps between injury prevention research and safety promotion practice. Firstly there is a gap between efficacy and effectiveness. Glasgow et al (2003) state that the transition from researching what works (i.e. efficacy and effectiveness research) to how to make it work (i.e. implementation research) is a critical step that is not necessarily straight forward. Glasgow and Hanson both agree that often missing in the injury prevention research is contextual complexity. Success is influenced by multiple inter-related contextual factors within a target group or community. Green (2001) has also challenged this oversight; 'Where did the field get the idea that evidence of an intervention's efficacy from carefully controlled trials could be generalised as 'best practice' for widely varied populations and situations?' (pp. 167).

The second gap is the research-to-practice gap, where the implementation of a preventative strategy becomes problematic. Whilst researchers frequently report individual impacts of interventions, measures of the process of the implementation, sustainability and population impact are frequently overlooked. In a systematic review of 27 articles of community based interventions, efficacy was reported in 100% of articles and reach (participation rates) was reported in 88% of articles, however implementation was only reported in 59% of papers and adoption in 11% of articles. No articles commented on the maintenance of the intervention (Dzewaltowski et al, 2004). In sports medicine research, the situation is even worse. Klugl et al (2011) completed a review of 12,000 sports injury prevention manuscripts. Only 4% assessed the effectiveness of an intervention and less than 1% reported the implementation and effectiveness of the intervention. The authors concluded that it was clear from the paucity of implementation studies that there remains a wide gap between our knowledge of effective prevention programmes and our ability to successfully implement them. Interestingly, less than 2% of the studies reviewed examined the effectiveness of prevention programmes in the real world context. Klugl et al (2011) also concluded that whilst it is clear that these studies are very difficult to perform, the difficulty should not deter researchers from seeking the evidence to prevent injuries in real life situations.

Finally, Hanson et al (2014) propose the 'injury-prevention-to-safety-promotion' gap. This gap relates to the dissemination and widespread adoption of sports injury intervention and argues that such social objectives can only be realised in the context of a community and the organisational and political processes that shape sports delivery. Evidence that is compelling for researchers, may not be automatically accepted by those in a position to implement an intervention or policy.

To overcome these gaps between injury prevention research and safety promotion practice, researchers, clinicians/practitioners and members of the target community or sporting bodies need to work together (Hanson et al, 2014). This is highlighted below in figure 1.5.

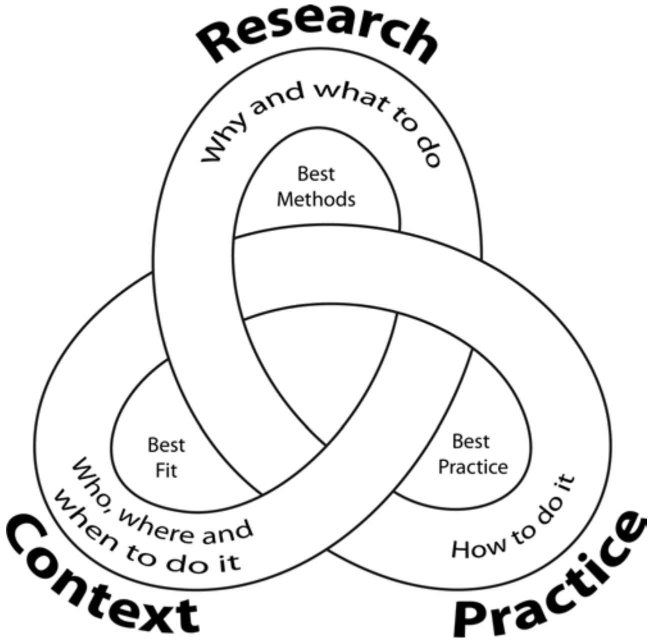



Figure 1.5 Integrating expertise to ensure comprehensive, evidence based interventions that are practical and relevant when applied in the real world (Hanson et al, 2014).

Beyond Van Mechelen's sequence of prevention, Finch's TRIPP model has been successfully used to change the laws of the game within a number of sports. Such examples include the use of protective eyewear in squash players (Eime et al, 2005) and tackle law in New Zealand rugby union (Simpson et al, 2002; Chalmers et al, 2004). Whilst interesting to note, it is not within the remit of this study to consider broader changes to sporting legislation regarding the implementation of a lumbo-pelvic-hip injury reduction strategy in rugby union. It is however pertinent to note that researchers (e.g. Finch, 2006) have criticised the gap between artificial studies, conducted in an 'ideal setting' with influences or resources that are only supported during the initial research period, and real-life. This study aims to be high in ecological validity, undertaken in the real world setting.

A final addition to the theoretical sports injury prevention approaches was published in 2018 (O'Brien et al). This model is named the Team-sport Injury Prevention (TIP) cycle in response to Fuller (2004) and Donaldson et al (2013) notion that practitioners working at the injury prevention 'coalface' will be better served by a model more reflective of risk management approaches. O'Brien and Finch (2014) also called for a model that is simple, directly applicable to the team's specific context and acknowledges real-world implementation challenges. This new TIP cycle reflects the cyclical nature of real-world injury prevention, requiring ongoing evaluation and adaptation of preventative strategies.

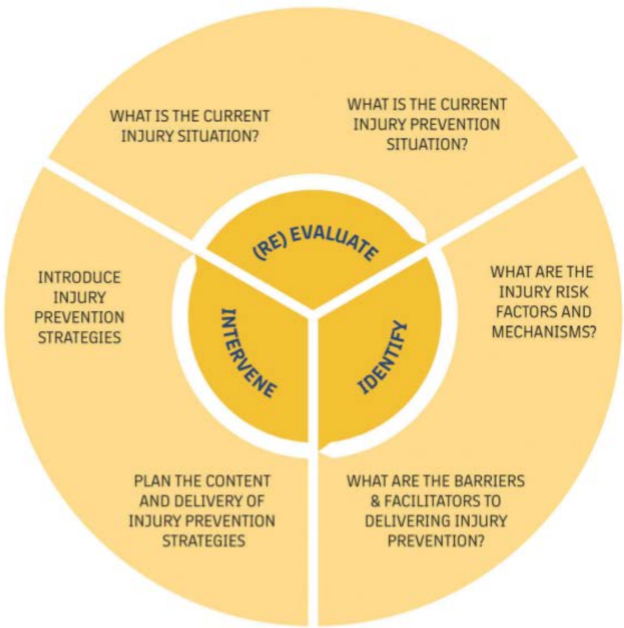



Figure 1.6 The Team-sport Injury Prevention (TIP) cycle (O'Brien et al, 2018).

In phase 1, evaluation is concerned with establishing the current injury situation (with injury surveillance data) and reflecting on the current injury prevention strategies. O'Brien et al also recommends that sports teams consider how sports injury prevention programmes are being delivered, e.g. in an exercise based reduction strategy teams should consider the types of exercises, frequency of the exercises, sets and repetitions, recovery time, concurrent high speed running load.

In phase 2, identification, teams should explore the risk factors and mechanism underpinning the injuries identified in phase 1 and should primarily be driven by the teams internal data e.g. from screening results. Secondary to this, consideration should be given to the established risk factors from the published literature. In phase 2, the sports team is encouraged to identify barriers and facilitators to delivering injury prevention programmes. Such barriers may relate to the content and nature of the preventative programme, how it may be delivered or supported by players, coaches and support staff.

Phase 3, intervention, involves planning both the content and delivery on the injury prevention strategy. This process is acknowledged to be influenced by the teams current situation, the identified risk factors and implementation barriers/facilitators, published injury prevention research and team members previous experiences from working in the injury prevention field. As a cycle, this process is subject to ongoing re-evaluation and modification.

As this model is only recently published, no research to date has implemented it or reviewed its effectiveness.

## 1.5 Injury Prevention Programmes in Sport

In practice, evidence to support injury prevention programs can be found in many sports such as Football and Basketball. The Federation Internationale de Football Association (FIFA) 11+ was developed in 2006 in cooperation with the Santa Monica Sports Medicine Foundation (SMSMF), and the Oslo Sports Trauma and Research Centre (OSTRC), as a complete warm up programme to prevent non-contact injuries in amateur football players (Bizzini and Dvorak, 2013). The FIFA 11+ involves eleven or more pre-training warm up exercises and has shown a significant reduction in non-contact football injuries (Soligard et al, 2004; Owoeye et al 2014; Silvers et al, 2015; Steffen et al, 2013). The FIFA 11+ programme has also been applied to male elite Basketball Players (Longo et al, 2012). In female soccer players, the Prevent Injury and Enhance Performance (PEP) programme was introduced to reduce the incidence of Anterior Cruciate Ligament (ACL) injuries (Mandelbaum et al, 2005). The PEP programme also uses 19 warm-up based exercises and has been shown to significantly reduce ACL injury (Mendelbaum et al, 2005; Gilchrist et al, 2008). Both the PEP and FIFA 11+ involve educating coaching staff on the delivery of the specific warm up exercises. The main features of both the FIFA 11+ and the PEP programmes are their simplicity – designed to include a small number of exercises with educational information on how to perform the exercises widely available in multimedia formats for easy dissemination to coaches and players.

Within Rugby Union, three national sporting bodies have adopted evidence based approaches to dealing with rugby injuries, specifically catastrophic head, neck and spinal injuries. In 2001, New Zealand Rugby Union introduced RugbySmart in which coaches and referees are specifically educated about player conditioning, safe techniques in the contact phases of the game and injury management (New Zealand Rugby Union, 2001). The Australian Rugby Union operates SmartRugby, an occupational health and safety programme similar to the education component of RugbySmart (Australian Rugby Union, n.d.). Both programmes are mandatory for all coaches and referees. In 2008, the South African Rugby Union introduced BokSmart (South African Rugby Union, 2008). This is also modelled on RugbySmart and aims to achieve behavioural changes to reduce catastrophic injuries. All three programmes focus on good injury management and primary prevention such as warm-up, safe technique and employing the rules of fair play (Freitag et al, 2015). In Scotland the “Are You Ready to Play?” programme was launched in 2009 aimed at 11 to 16 year olds (Scottish Rugby, 2009). Its focus is on tackle and ruck technique, ‘core stability’, speed and agility and is considered more of a physical preparedness programme than injury prevention programme.

The Rugby Football Union of England recently commenced the Functional Movement Competency in Rugby project which is both an injury surveillance and prevention system (University of Bath, 2015) specifically aimed at under 18, under 16 and under 15 players and will focus on the development of warm-up and training programmes. In a recent publication, Attwood et al (2017) examined the effectiveness of a generic Functional Movement Screen™ (FMS) on predicting injury incidence in community male rugby union players. The initial results show that Functional Movement Screening™ has no association with injury incidence but a 1 point increase in FMS score is associated with a 10% reduction in injury burden (RR, 90%CI = 0.9, 0.8-1.0), and asymmetrical and/or painful movements during the FMS were associated with a 3 fold increase (RR, 90%CI = 2.9, 1.1 – 7.8) in risk of injury burden (Attwood et al, 2017). As a follow on to this study, Attwood et al (2017) examined the efficacy of a Movement Control Injury Prevention Programme in adult male community rugby union players during the 2015/16 season. Forty one clubs completed the full study and submitted data. This prospective, cluster randomised (single blinded) controlled design study recruited 22 clubs to the intervention group and 19 to the control group. As part of the intervention, clubs completed a 42-week exercise programme that incorporated proprioceptive, balance, cutting, landing and resistance exercises specifically targeted at Anterior Cruciate Ligament (ACL) injury risk factors. The intervention was split in to seven, six-week progressive phases. Clubs would complete the programme at their twice weekly training sessions and pre-match. The sessions were designed to include 5-10 minutes of small-sided games, and 15 minute of main programme content. The specific programme has not been published, though an online supplement exemplifies one intervention phase. It is also not clear who delivered the intervention, e.g. coaches or medical staff. Results from this intervention demonstrate positive findings including a 40% reduction in the incidence of lower limb injury and a 60% incidence in concussive injury for the intervention group. However, no clear effects on overall injury outcomes were reported. A number of criticisms can be made of this study. The study employed a one-size-fits-all approach to injury prevention programmes rather than tailoring the intervention based upon individual intrinsic risk factors. The study also used a different definition of time-loss injury compared to the one provided by the Injury Consensus Group (Fuller et al, 2007). In this study, injuries were only recorded where a player was absent from match play (≥ 8 days). This potentially under reports the injury incidence as injuries are typically recorded as time-loss injuries where a player is unable to take part in training or match play. We also cannot compare the injury incidence to previous seasons, as surveillance was not reported for the 2014/15 season. Reproducibility of this study is not possible as the exact intervention programme has not been published. Finally, this study was not performed on professional rugby union players.

Only RugbySmart and BokSmart have completed all four stages of van Mechelens' sequence of prevention. The effectiveness of these programmes is limited with only one study examining BokSmart (Brown et al, 2014) and two studies examining RugbySmart (Gianotti et al, 2009; Quarrie et al, 2007). Gianotti et al (2009) examined the effect of the introduction of RugbySmart in the 2001 season in New Zealand. They collected injury surveillance data using the Accident Compensation Corporation (ACC), a New Zealand Government-taxpayer funded monopoly. Injury incidence was recorded as the rate of injury claims per 100,000 players based upon the New Zealand Rugby Union player registration system data. Rugby Smart is delivered in community based workshops to coaches and referees with the aim of improving contact area skill and techniques. The aim of RugbySmart is to reduce moderate to serious injuries to the neck, spine, shoulder, knee, leg and ankle. Across the 5 seasons examined (2001-2005) Gianotti et al (2009) observed a reduction in injuries sustained to targeted areas without subsequent decreases in injuries to non-targeted areas. They conclude that workshops delivered as part of a community focused injury prevention programme did reduce targeted injuries, through purported changes to injury prevention behaviours. Unfortunately, a non-standard method for injury surveillance data collection was used making comparisons to other research difficult and no baseline data was collected. It may have been useful to report on the ACC data for the 2000 season, prior to the launch of RugbySmart as we are unsure of the stability of injuries per 100,000 players. Also the mechanism of affect (I.e. behaviour change) was only hypothesised and no record of mechanism of injury or phase of play was recorded making judgements on risk taking behaviours challenging. Quarrie et al (2007) also appraised the RugbySmart programme but reviewed its impact on disabling spinal cord injuries sustained due to rugby union participation. Again using ACC data, that was cross checked to the New Zealand Rugby Foundation so as to gain additional information on the phase of play the injury was sustained in, they compared spinal cord injuries sustained between 1976-2001 to predicted and actual spinal cord injuries sustained from 2001-2005. Predicted data was generated using generalised linear modelling however the current New Zealand player registration system was only introduced in 2001, so any estimates of the number of players participating in rugby union prior to 2001 were made from player registrations and an evaluation of competition draws that may not accurately reflect the number of players participating in rugby union in New Zealand at that time. An underestimation of player numbers prior to 2001 may subsequently effect the ability of the study to correlate injury data and any subsequent regression/prediction. Results from this study nevertheless show that between 2001-2005, serious spinal cord injury was predicted to be 18.9 injuries per 100,000 players however, it was only 8/100,000 players. Serious spinal injuries sustained from scrummaging was predicted to be 9/100,000 players however this was recorded as 1/100,000 players. The authors concluded that the RugbySmart educational initiative coincided with a decrease in the rate of disabling spinal injuries from rugby union participation and scrummaging in New Zealand.

Brown et al (2014) examined the effect of Boksmart on catastrophic head and neck injuries in South African Rugby Union between its pre-launch in the 2008/2009 season to post implementation in the 2010-2013 seasons. Essentially, Boksmart is identical to the RugbySmart programme offered in New Zealand. South African researchers acknowledge the recognisable similarities, such as their programme structure which educates coaches and referees in an attempt to prevent catastrophic injuries in players. However, South African researchers also highlight that the two countries present very different environments to the implementers of these respective programmes (New Zealand and South African Rugby Unions), with South Africa still classified as a “developing nation” with huge socioeconomic disparity among players, coaches and referees.  Again this study estimated player numbers and assumed the player number was constant across the study period. Injury surveillance was not completed in accordance with current consensus guidelines, however medical teams that had dealt with a catastrophic head or spinal injury completed a questionnaire and submitted this to the Boksmart Serious Injury Case Manager. A Poisson regression analysis was completed comparing pre Boksmart absolute injury rates in the 2008/2009 season to post Boksmart absolute injury rates in 2010-2013. Results showed that across the study, 71 rugby related catastrophic injuries were recorded, averaging 12 per year. The maximum recorded in a year was 15 injuries, during the first Boksmart implementation year (2009) and the minimum injuries was 4, recorded in the pre Boksmart season (2008). When the results were adjusted for the age of the participants, a 39% reduction in catastrophic injuries was noted for junior players though no significant change was observed for senior players.

Both programmes administered a one-size-fits-all education based intervention aimed at reducing the community/population risk. Both programmes claim to be successful in reducing the number of injuries by introducing behavioural changes among players. Improvements are especially noted in behaviours that lead to catastrophic injuries (Gianotti et al, 2009; Brown et al, 2014).

To date, no studies have completed a full sequence of prevention in Rugby Union aimed at *tailoring* injury reduction based upon individual player risk. No injury reduction programme currently exists for non-contact soft tissue injuries in Wales at a professional level. The unique contribution to knowledge made by the specific study in question is therefore highlighted.

## 1.6 Anatomy of the Hip and Groin

Before we consider developing an intervention based upon intrinsic risk factors it would be useful to refresh our understanding of the regional anatomy. The hip and groin region is anatomically complex as it includes a number of joint articulations and is the attachment site for a number of muscles. The groin region itself is not well defined. The Medical Subject Headings (MeSH) term describes the groin without defining specific anatomical borders as “the external junctural region between the lower part of the abdomen and the thigh” (Groin - MeSH - NCBI. http://www.ncbi.nlm.nih.gov/mesh/?term=Groin. Accessed May 14, 2016). Anatomically, it comprises the pelvic girdle (ilium, ischium and pubis), the lumbar spine, sacrum and its articulation with the ilium (the sacroiliac joint) and the hip joint – a ball and socket joint that attaches the femoral head to the acetabulum of the pelvis. When combined these make up the lumbo-pelvic-hip (LPH) complex.

## 1.7 Osteology

The ilium, ischium and pubis are fused together to form the pelvic girdle. Within the acetabulum of the pelvic girdle, the femoral head attaches. The acetabulum is deepened by a labrum. The sacroiliac joint is the articulation between the sacrum and the ilium located at the posterior of the LPH complex. It is a synovial plane joint and is a primary shock absorber for this complex. Anteriorly the two halves of the pelvic girdle are attached via the pubic symphysis (Palastanga and Soames, 2012).

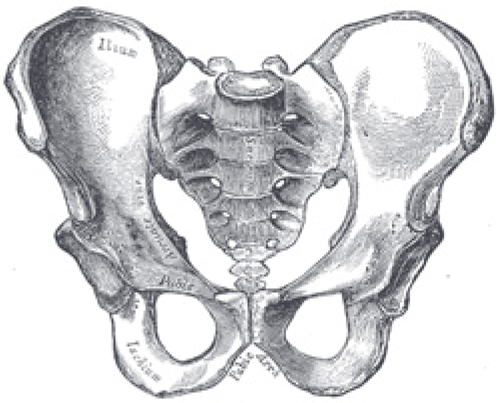



Figure 1.7 Male Pelvic Osteology (Grey, 1918).

## 1.8 Muscle Morphology

A number of muscles attach to or around the LPH complex. The muscles of the groin can roughly be divided in to adductor muscles, the abductor muscles, the abdominal muscles and the hip flexor muscles. Posteriorly we can also consider the hip extensors.

*The hip flexor muscles*

The primary hip flexors are the iliopsoas, sartorius, tensor fascia latae, rectus femoris, adductor longus and pectineus. The secondary hip flexors are the adductor brevis, gracilis and anterior fibres of gluteus minimus. The iliopsoas is a large and long muscle that attaches from the 12$^{th}$ thoracic vertebrae to the proximal femur. Anatomically it is the fusion of iliacus and psoas major. The iliacus attaches on the iliac fossa and the extreme lateral edge of the sacrum. The psoas major attaches along the transverse processes of the last thoracic and all lumbar verterbrae including the intervertebral discs (Hansen et al, 2006). The ilipsoas muscle produces force that crosses the lumbar and lumbosacral regions and the hip (Neumann, 2010a). Sartorius is the longest muscle in the body and originates at the anterior-superior iliac spine. It is a thin fusiform muscle with its distal attachment at the medial surface of the proximal tibia. The tensor fascia latae attaches to the ilium just lateral to the sartorius. This short muscle attaches to the iliotibial band, which inserts in to the lateral tubercle of the tibia. The tensor fascia latae is a primary flexor and abductor of the hip (Neumann, 2010b). The long head of the rectus femoris has a proximal attachment on the anterior-inferior iliac spine, with the reflected head attaching on to the superior rim of the acetabular labrum and hip joint capsule. The rectus femoris is responsible for approximately 1/3$^{rd}$ of the total isometric hip flexion torque (Markhede and Stener, 1981). There is a synergistic relationship between the hip flexors and the lower abdominals. The abdominal muscles must generate a potent posterior pelvic tilt of sufficient force to neutralise the strong anterior pelvic tilt of the hip flexor muscles (Neumann, 2010a).

*The hip extensor muscles*

The primary hip extensors are the gluteus maximus, the hamstrings (the long head of biceps femoris, the semitendinosus and the semimembranosus) and the posterior head of the adductor magnus. The posterior fibres of the gluteus medius and anterior fibres of the adductor magnus are the secondary extensors however when the hip is flexed to greater than 70º most adductors (with the possible exception of pectineus) are capable of assisting hip extension (Neumann, 2010a). The gluteus maximus has many proximal attachments from the posterior ilium, sacrum, coccyx, sacrotuberous and posterior sacroiliac ligaments and adjacent fascia to the iliotibial band of the fascia lata and the gluteal tuberosity of the femur (Neumann, 2010b). The hamstring muscles have their proximal attachment on the posterior aspect of the ischial tuberosity and attach distally to the tibia and fibula. The long head of biceps femoris tendon attachment to the ischial tuberosity is considered to be fused and continuous with the sacrotuberous ligament (Van Wingerden et al, 1993, Figure 1.8). Connections between the gluteus maximum and the sacrotuberous ligament have also been found (Vleeming, Stoeckart and Snijders, 1989).  The sacrotuberous ligament is fused proximally with the thoracolumbar fascia and the deep multifidus muscle of the lumbar spine.

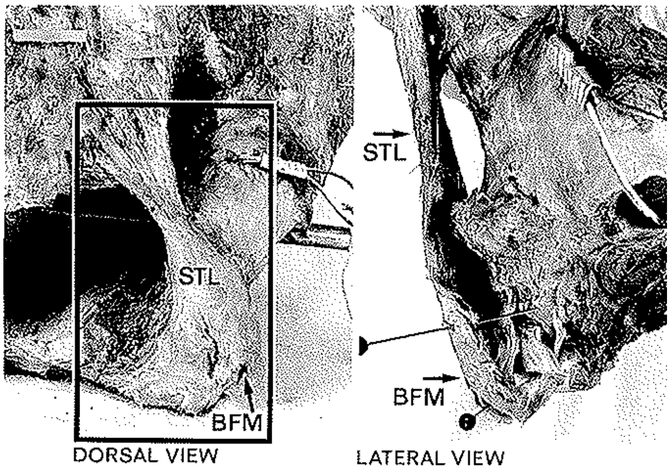



Figure 1.8 The fusion of the Biceps Femoris muscle (BFM) with the Sacrotuberous ligament (STL) in a human cadaver (Van Wingerden et al, 1993).

Adductor magnus posterior head also attaches to the posterior aspect of the ischial tuberosity (Neumann, 2010a). The hip extensors as a group produce the greatest torque across the hip than any other muscle group, furthermore with the hip in a flexed position many of the adductor muscles produce an extension torque, thereby assisting the primary hip extensors (Hoy, Zajac and Gordon, 1990).

*The abductor muscles*

The primary hip abductor muscles include all fibres of the gluteus minimus and gluteus medius, and the tensor fascia latae. The piriformis, sartorius and rectus femoris are considered secondary hip abductors. The gluteus medius is the largest of the hip abductors comprising 60% of the total abductor muscle cross sectional area (Morcelli et al, 2016). The muscle attaches distally to the lateral and superior-posterior aspects of the greater trochanter (Palastanga and Soames, 2012). The proximal attachments on the upper ilium combined with the distal attachment provide the greatest abduction moment arm of all the abductor muscles (Dostal, Soderberg and Andrew, 1986). Gluteus minimus lies immediately deep to medius and accounts for approximately 20% of the total abductor muscle cross sectional area (Clark and Haynor, 1987). The tensor fascia latae is the smallest primary abductor and accounts for only 11% of the muscle cross sectional area (Clark and Haynor, 1987). This muscle arises from the outer lip of the iliac crest, lateral to the anterior superior iliac spine and blends distally with the iliotibial band.

*The adductor muscles*

The adductors comprise of the adductor longus, adductor magnus, adductor brevis, pectineus and gracilis (Neumann, 2010b). Secondary adductors include the biceps femoris long head and the gluteus maximus (especially the posterior fibres), quadratus femoris and obturator externus (Neumann, 2010a). During rapid or complex movements involving both lower extremities it is likely that many of the adductor muscles are bilaterally and simultaneously active to control femoral-on-pelvic and pelvic-on-femoral hip movements. As mentioned previously the adductors are also considered important flexors and extensors of the hip. The nearly constant triplanar biomechanical demand placed on the adductor muscles throughout a wide range of hip positions may partially explain their relatively high susceptibility to strain injury (Neumann, 2010a). The adductor longus is generally considered to be the most important muscle in relation to acute and chronic groin pain and as such has been examined in several studies (Davis, Stringer and Woodley, 2012; Strauss, Campbell and Bosco, 2007; Tuite et al, 1998). The adductor muscles attach inferiorly to the pubic ramus and are very closely positioned making differentiation difficult.

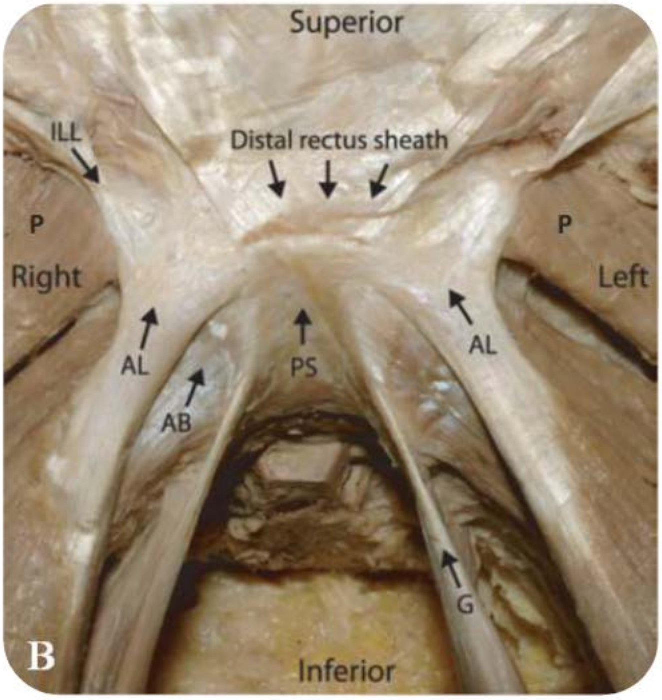



Figure 1.9 Anatomical proximal attachment of the adductor muscles (Norton-Olds et al, 2013). AL = adductor longus, AB = adductor brevis, P = pectineus, G = Gracilis, PS = pubic symphysis, ILL = Ilioinguinal ligament.

*The abdominal muscles*

The abdominal muscles attach to the pubis and ilium from a superior position. The internal and external obliquus, transverse abdominis, rectus abdominis and pyrimidialis muscles all have their attachments at the LPH complex. The rectus abdominis is thought to have a fascial continuation over the pubis with the adductor longus, making them one structural entity, though this is still debated in the literature. Some argue that there is direct structural connection between the rectus abdominis and the adductor longus (Omar et al, 2008). In contrast, other studies appear to describe the rectus abdominis attachment at the pubic crest, and a potential proximal-distal connection that could be due to mutual insertions onto the anterior capsular tissues of the pubic symphysis (Robinson et al, 2007).


Figure 1.10 A MRI image taken in the sagittal plane showing the continuation of Rectus Abdominis (RA) with Adductor Longus (AL) over the Pubis (P). Ap recognises the aponeurosis, Pesquer et al (2015).

The lower abdominal wall is composed of several additional layers that form the rectus sheath anterior to the rectus abdominis. The transverse abdominis is the deepest abdominal muscle and is described to fuse medially with the internal oblique to form a conjoint tendon distally.

The purpose of this muscle morphology review is to demonstrate the significant connections between the regional anatomy of the lumbar-pelvic-hip region with overlaying of muscle actions and muscle attachments in close proximity.

## 1.9 Hip and Groin Diagnostic Terminology

Groin pain in athletes is a common problem and renowned for being a complex issue. The wide variety of possible injuries in numerous anatomical structures and high prevalence of ‘abnormal findings’ in asymptomatic athletes contribute to the complexity. As a result, a meeting held in Doha developed a consensus on a clinically based taxonomy using three major categories (Weir et al, 2015).

Firstly groin pain was divided in to several subsections and is annotated in figure 1.11:-

- Adductor-related groin pain presents clinically as adductor tenderness accompanied with pain on resisted adduction testing.
- Iliopsoas-related groin pain presents with iliopsoas tenderness and pain on resisted hip flexion and/or pain on stretching of the hip flexors.
- Inguinal-related groin pain presents as pain located in the inguinal canal region with tenderness of the inguinal canal on palpation. There is however, no palpable inguinal hernia present. Pain can be aggravated with resistance testing of the abdominal muscles or on Valsalva/cough/sneeze.
- Finally, pubic-related groin pain presents as local tenderness of the pubic symphysis and the immediately adjacent bone.

Figure 1.11 Defined clinical entities for groin pain from the Doha Consensus Agreement (Weir et al, 2015).

Secondly the consensus statement encourages clinicians to establish if there is a hip-related groin pain element. This component can be hard to distinguish from other causes and may co-exist with other types of groin pain. A comprehensive subjective and objective clinical examination including passive range of motion and hip special tests such as the flexion-abduction-external rotation (FABER) and flexion-adduction-internal rotation (FAIR) tests can be used to identify a hip component. Such tests can help the clinician identify potential intra-articular hip pathology such as labrum or femoroacetabular injury as a source of the patients groin pain.

Finally, Weir et al (2015) labelled the third taxonomy ‘other conditions causing groin pain in athletes'. The Doha group acknowledged the many other potential causes of groin pain in athletes including orthopaedic, neurological, rheumatological, urological, gastrointestinal, dermatological, oncological and surgical causes, but this list is not exhaustive as many rare conditions could possibly refer pain in to the groin region. This classification system is due for a review in December 2018.

### 1.10 Incidence of Sports Related Groin Pain

There are a number of challenges in the reporting of the incidence of sports related groin pain. Firstly, studies use a wide and varied vocabulary in the diagnostic labels they present. Studies are lacking in specific injury diagnosis terminology – such as those outlined in section 1.9. The methods of injury reporting also vary with some studies reporting incidence as a percentage of total injuries sustained whilst others report incidence per 1000 hours of exposure. This makes comparisons between studies extremely difficult. Sports related groin pain rarely has an acute or traumatic onset. Rather these injuries often start insidiously, with no clear, single mechanism of injury. The patient may manage the injury through self-regulation and self-imposed limitations and will train fully with the team. Initially these injuries are not time-loss injuries, with the player still available for selection, however the player may be in pain and may or may not seek out treatment. One study by Harøy et al (2017) estimates only about one-third of all groin problems result in time loss. We can therefore assume that sports related groin pain injuries that are considered time-loss injuries, and are therefore recorded on the teams injury surveillance data, are merely the 'tip of the iceberg' as at any given point in time a larger proportion of players continue to participate despite having groin-related complaints with associated impairments or reduced performance (Walden, Hagglund and Ekstrand, 2015; Harøy et al, 2017;

Thorborg et al 2017a & b).

In football, 19% of all time loss injuries at a senior level have been attributed to groin injuries (Walden, Hagglund and Ekstrand, 2015). At a Champions League level team over a period of 7 years, groin injuries accounted for 12-16% of all injuries. Adductor relates injuries accounted for 2/3rd of all groin injuries sustained with the remainder being hip flexor strains, hip injuries and inguinal injuries (Werner et al, 2009). In Danish sub elite football, over half the groin pain diagnoses were from adductor strains, followed by iliopsoas strains and abdominal related groin pain (Hölmich et al 2014). In Hölmich et al's study it was reported that only 2/5th of groin injuries were acutely traumatic with the majority of injuries had an insidious onset. Ekstrand, Hägglund and Walden (2011) reported on general muscle injuries in professional football. They found that an average 25 player squad will sustain 4 hip and groin muscle injuries per season. The adductor muscle is the second most frequently injured muscle (23%) behind the hamstring muscles (37%).

In Australian Rules Football groin injuries are the most frequently reported injury location (Orchard, Seward and Orchard, 2013). Groin injuries account for approximately 9% of all injuries, or approximately 3/1000hours exposure (Orchard, 2015). This equates to an average of 3 new injuries per club per season (Orchard, Seward and Orchard, 2013). There is also a high recurrence rate reported in Australian Rules Football. According to Orchard, Seward and Orchard (2013) 23-25% of players experience groin pain following return to play compared to 12-18% in football (Ekstrand, Hägglund and Walden, 2011).

In rugby league, Gibbs (1993) reported that groin injuries accounted for 11% of all injuries sustained in one Sydney based professional club. The most common injury to the groin was a muscle/tendon injury. In another study, O'Connor (2004) reported that 23% of all professional rugby league players sustained an adductor injury over a 2 year period.

Ice hockey has consistently demonstrated moderate groin injury rates in American (Dalton et al, 2016; Emery, Meeuwisse and Powell, 1999; Tyler et al 2001), Danish (Jorgensen & Schmidt-Olsen, 1986), Swedish (Lorentzon, Wedren & Pietila, 1988), Finish (Molsa et al, 1997) and International teams (Tuominen et al, 2015). The incidence in these studies is reported as 3-11% of all injuries, or as having an incidence of 1/1000hours of general exposure and 3/1000 match hours.

In rugby union hip and groin injuries have been reported as accounting for 8% of all injuries or 0.6/1000 hours exposure (Whitehouse et al, 2016). Adductor injuries specifically have been reported to have an incidence of 0.8/1000 training hours and 2.5/1000 match hours (Brooks et al 2005 a & b). A very high incidence on groin injuries in Welsh International matches has also been reported as 21/1000hours (Moore, Ranson and Mathema, 2015).

## 1.11 Aims and Objectives

This study aims to develop and implement a tailored injury reduction programme based upon the players' unique set of individual intrinsic risk factors. It does this with limited resources (e.g. staff, time, equipment, and budget) and aims to demonstrate that such an approach is possible and sustainable in a professional rugby union environment. This study also aims to investigate players' perceptions of injury reduction programmes, in order to facilitate implementation and adherence to injury reduction programmes.

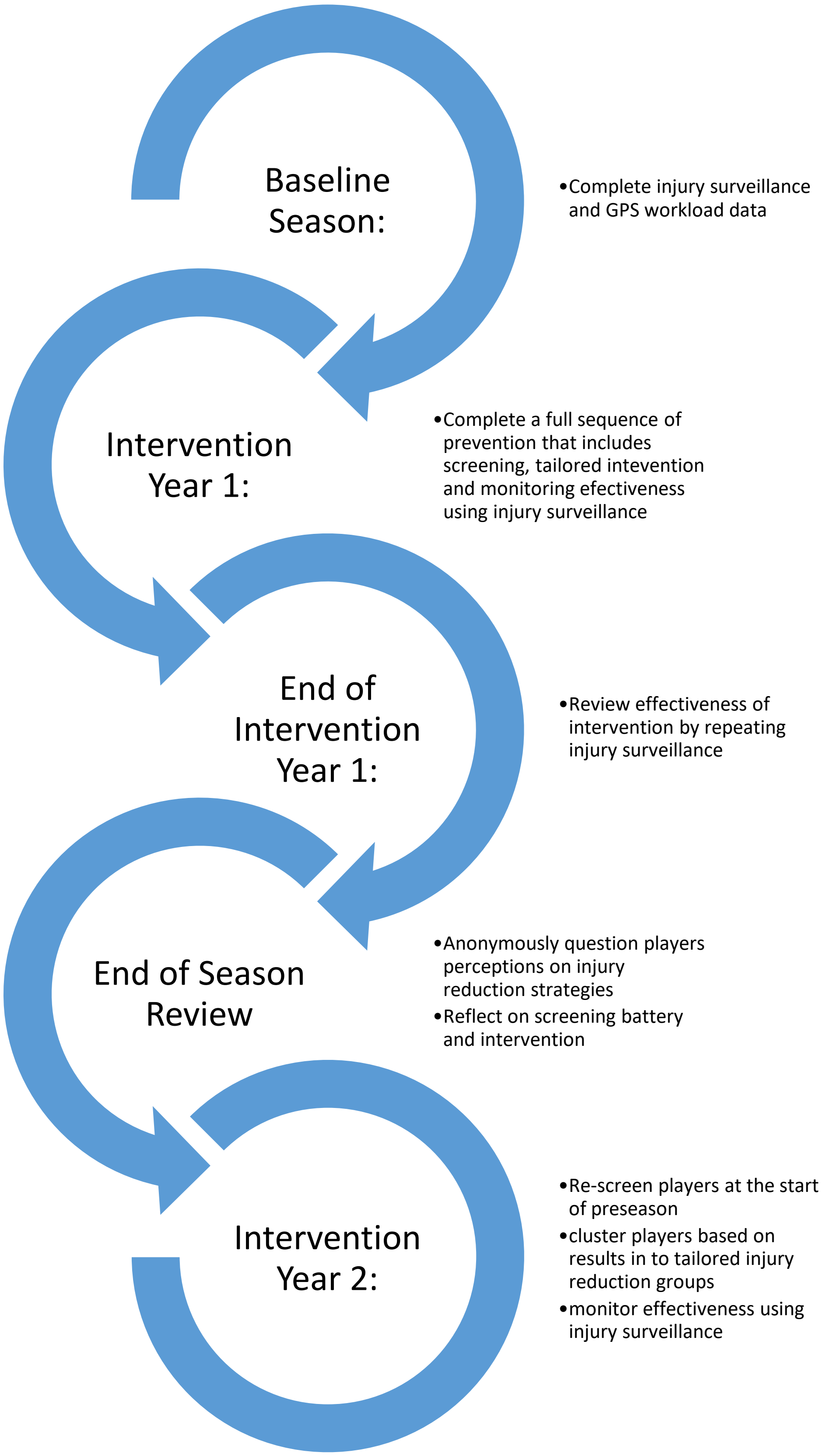
## 1.12 Summary

In this introductory chapter, the concept of sports injury risk has been introduced, along with the risk factors for sports injury risk. A theoretical framework for injury prevention has also been presented with examples of national injury prevention programmes currently being used in sport. Finally, a brief overview of the regional anatomy and the incidence of sports related groin pain was presented. It is clear from this brief introduction, that the hip and groin region is complex, with significant variations in anatomical and diagnostic nomenclature that compound efforts to cohesively research this field. Comparisons between literature are challenging, and whilst many examples of stage one of the sequence of prevention (injury surveillance) are available, very few studies exist that show the full sequence of prevention through to completion, and even then – such studies provide only a 'mass vaccination' approach by administering a few generic exercises during a warm up to all players or a coach education intervention. This conflicts with the Prevention Paradox theory (Rose, 1981) which highlights that such a strategy may benefit the community as a whole, but does not serve the high-risk individual and as such fails to consider the impact of a significant time loss injury, e.g. lumbo-pelvic-hip injury, on a single player.

Chapter 2 will present a systematic literature review aimed at understanding the current literature and its limitations so as to inform the subsequent intervention. Chapter 3 reports on the methodology used in this study. Phase one of this thesis will report on the implementation of a tailored LPH injury reduction programme in the context of one professional rugby union team across two seasons. Phase two will present players perceptions and reflections on injury reduction strategies and finally, phase three will present the results of a subsequent season on tailored LPH injury reduction strategy and the final season where all screening and interventions were withdrawn.

Figure 1.12 presents an overview of the three year research project completed as part of this thesis.

Figure 1.12 An overview of the research process timeline for this doctoral thesis.



# Chapter 2 Literature Review

## 2.0 Introduction

The previous chapter introduced some of the complex issues surrounding injury reduction, specifically of the LPH region, in sport. The Van Mechelen sequence of prevention model, presented in figure 1.0 described stage one of the sequence of prevention as establishing the extent of the injury problem by determining the injury incidence and severity. Section 1.10 briefly presented the incidence of LPH injuries in sport. This chapter will specifically outline injury surveillance practices in professional rugby union and discuss the incidence of LPH injuries in professional and international rugby union. Stage two of the sequence of prevention (Van Mechelen et al, 1987) describes the need to examine and understand the aetiology or causes of the injury and the mechanism of injury before the practitioner progresses to the third stage; developing and implementing an injury 'prevention' programme. This appraisal of aetiology and mechanisms of injury is typically done as a systematic literature review and so following the section on injury surveillance methods, a systematic literature review of the risk factors for sports related groin pain and exercise programmes for groin injury reduction will be presented. Finally the limited literature surrounding players' perceptions of injury reduction strategies will be presented.

## 2.1 Introduction to Rugby Union

Rugby union is a contact invasion sport involving 15 players per side (8 forwards, 7 backs) and is played in over 100 countries worldwide (World Rugby, 2015). As a contact sport, players frequently experience high-impact collisions resulting in high levels of musculoskeletal and neurological injuries (Williams et al, 2013). Rugby Union has one of the highest reported incidences of match injuries amongst all professional team sports (Brooks and Kemp, 2008). For match play the reported incidence of injury has been as high as 81 injuries sustained per 1000 hours exposure, and 3 per 1000 hours exposure for training injuries (Williams et al, 2013). Moreover, the contact and collisions that are inherent to elite rugby union, alongside changes to players' physical characteristics and match activities, have raised concerns regarding the level of injury burden (as measured by time loss) associated with the professional game (Williams, 2015). When sustained, injuries during matches resulted in an average of 20 days lost compared to an average of 22 days lost for training injuries. Muscle/tendon and joint (non-bone)/ligament injuries were the two most prevalent injury groups, whereas fractures and bone stress injuries had the highest average severity. Most notably, the lower limb was the body region with the highest injury incidence, while upper limb injuries were most severe (Williams et al, 2013).

Given the burden of such injuries, injury reduction strategies that aim to modify injury risk have been promoted for various reasons. Such justifications of reduction strategies include: player welfare, the financial cost of injury to the club, and player, and team success. Professional Rugby Union in Wales is limited to the four Regional Rugby Teams (Scarlets, Ospreys, Blues and Dragons) located in south Wales. In December 2011, a salary cap of £3.5million was introduced to the four Regional Rugby Teams (Gallagher, 2011). French professional rugby teams, in comparison have a notional cap of £8.6million though even small professional teams such as Lyon are reported to spend £14million on player wages (Gallagher, 2011). In the English professional league, a player wage cap of £7million was introduced however this value excludes the salaries of two “marquee signings” that remain outside of the cap (Harries, 2015). It is clear that the Regional Teams in Wales are striving to compete with European counterparts on relatively limited budgets. No available data exists relating to the financial cost of sports injury to the Professional Rugby Union team however, in Australian Rules Football (AFL) the average cost of a single hamstring strain injury in 2012 was calculated to be $40,021 AUS and the average cost to AFL clubs of games missed due to hamstring strain injury was calculated to be $245,842 AUS (Hickey et al, 2014). The average player salary in the AFL for 2012 was $251,559 AUS, which is a comparable to the average salaries paid in Professional (Regional) Rugby Union in Wales.  It also worth noting that the association between player availability and team success has been demonstrated in various professional football cohorts (Hägglund et al, 2013), professional rugby league (Gabbett, 2004) and professional rugby union (Williams et al, 2015). From these studies, teams with more players available for selection throughout the season are more likely to finish the season in a higher league position. Given the cap on salaries in Welsh regional rugby, a lack of strength in depth in the squad may be an issue, and thus injury reduction strategies could be of greater importance.

To reduce sports related injuries, maximising player availability for team success and minimising the economic burden of injury on a team’s limited budget, injury reduction strategies are developed. The process starts with establishing the extent of the sports injury problem in a specific cohort, determining injury risk factors based on the intrinsic player characteristics and extrinsic sporting demands. A number of models of injury prevention have been developed and are discussed in chapter 1. The most commonly applied model is the sequence of prevention, developed by van Mechelen et al (1987). Once the most likely injuries are identified and understood, reduction based programmes are developed and employed. The effectiveness of the programme is monitored. Despite this model, there have been few published implementation or effectiveness studies in sports injury prevention (Klugl et al, 2010; Donaldson et al, 2016) and information about specific implementation components is scarce (O'Brien & Finch, 2014).

The following sections will explain the process of developing an injury reduction programme. It will start with explaining how information on injury in sport is defined and collected. It will then explain why the injury prevention approach selected was chosen for this study.

## 2.2 Injury Surveillance in Rugby Union

Before a prevention programme can be developed, understanding the injury landscape of a particular sport and possibly squad of players is essential. This process is typically termed injury surveillance.

Injury surveillance has been completed within several different sports, such as athletics, cricket, soccer and rugby union (Alonso et al, 2009; Alonso et al, 2010; Engebretson et al, 2013; Fuller et al, 2013; Hägglund et al, 2013; Ranson et al, 2013). The term 'injury surveillance' relates to an ongoing collection of data describing the occurrence of, and factors associated with, injuries (Pakkari et al, 2001). The success of any sports injury surveillance system and its widespread applicability are dependent upon valid and reliable definitions of sports injury, incidence and severity (Finch, 1997).

Injury occurs when energy is transferred to the body in amounts or at rates that exceed the threshold for human tissue damage (Baker et al, 1992). Sports injuries typically result from mechanical energy transfer (Meeuwisse et al, 2007). In rugby union, the definition of injury accepted by the Rugby Injury Consensus Group is as follows:

> *Any physical complaint, which was caused by a transfer of energy that exceeded the body's ability to maintain its structural and/or functional integrity, that was sustained by a player during a rugby match or rugby training, irrespective of the need for medical attention or time-loss from rugby activities. An injury that results in a player receiving medical attention is referred to as a 'medical attention injury' and an injury that results in a player being unable to take full part in future rugby training or match play as a 'time-loss injury' (Fuller et al, 2007.* P 329).

In rugby union, non-fatal catastrophic injuries are of particular interest and have been defined as a 'brain or spinal cord injury that results in permanent (greater than 12 months) severe functional disability' (Fuller et al, 2007. p. 329), where severe functional disability is defined as a loss of greater than 50% of the capability of the structure (WHO, 2001).

Recurrent injuries are defined as:

> *An injury of the same type and at the same site as an index injury and which occurs after a player's return to full participation from the index injury. A recurrent injury occurring within 2 months of a player's return to full participation is considered an 'early recurrence', one occurring 2 to 12*

*months after a player's return to full participation as a 'late occurrence', and one occurring greater than 12 months after a player's return to full participation as a 'delayed recurrence'* (Fuller et al, 2007. p 329.).

Injuries may be sustained during matches or training. Injuries that occur during match exposure are sustained during play between teams from different clubs, including trial games. Training exposure is defined as team-based and individual physical activities under the control or guidance of the team's coaching or fitness staff that are aimed at maintaining or improving the player's rugby skills or physical condition (Fuller et al, 2007).

In addition to reporting injury incidence relative to exposure, researchers are encouraged to report injury burden. Injury burden is calculated as the injury incidence rate multiplied by mean absence per injury (severity), expressed as number of injury days lost per 1000 player hours. As a measure it accounts for both frequency and severity of injuries, it has been purported as superior for assessing the impact of injuries upon team success, compared with injury rates alone, since injury burden relates more closely to player availability (Orchard, 2009; Brooks and Fuller, 2006; Arnason et al, 2004).

Injury severity indicates the time, in days, lost from match and practice. Specifically, injury severity is defined as the number of days that have elapsed from the date of the injury to the date of the player's return to full participation in team training and availability for match selection (Fuller et al, 2007). Injuries are grouped by their severity as slight (0-1 day), minimal (2-3 days), mild (4-7 days), moderate (8-28 days) and severe (greater than 28 days). Players who are unable to return to full participation are said to have suffered a ‘career-ending’ injury or ‘non-fatal catastrophic’ injury.

Injury incidence is a common indicator of occurrence in a population.  van Mechelen et al (1992) define injury incidence as the number of new sports injuries or accidents during a particular period, divided by the total number of sportspersons at the start of the period. It also gives an estimation of risk. If the figure obtained is multiplied by 100, a percentage rate of injury is obtained (Sturmans, 1984). Expressed in this way, sports injury incidence provides a ‘yardstick’ for the extent of the sports injury problem (van Mechelen et al, 1992).  Incidence rate of sports injuries is usually defined as a number of new sports injuries during a particular period (e.g. 1 year, 1 season) divided by the total number of sportsmen at the start of the period (population at risk). Injury incidence must be expressed relative to ‘exposure’ to allow for comparisons between groups or teams to be made. Exposure is defined as the number of hours during which a person actually runs the risk of being injured (van Mechelen et al, 1992). Kranenborg (1980) states that incidence figures that take no account of exposure are not a good indication of the true extent of the problem, nor can they provide a point of comparison for incidence rates in different sports. For this purpose, injury incidence is expressed as the number of injuries per 1000 hours of sports participation (Williams et al, 2015). The equation initially developed by Chambers (1979), then adapted by de Loës and Goldie (1988) has been used to calculate injury incidence taking exposure into account:

$$\text{Injury incidence} = \frac{(\text{No. of sports injuries per timeframe}) \times 1000}{(\text{No. of participants}) \times (\text{hours of sports participation/week}) \times (\text{weeks of the season/year})}$$

As a result of this, studies now express injury incidence as the number of injuries per 1,000 player-hours of (training and/or match) exposure.

Following the publication of the Rugby Injury Group Consensus guidelines (Fuller et al, 2007), research in the area of injury surveillance is encouraged to record injury incidence, injury severity, injury location, type of injury, mechanism of injury, and injuries sustained by foul or dangerous play where a violation of the laws of the game had occurred.

Injury surveillance research on professional rugby union players in Wales is limited. According to Moore et al (2014), during the 2012-2013 season, the professional game in Wales noted an injury incidence of 10 per 1000 hours exposure on average, with an incidence of 2 per 1000 hours exposure for training injuries and 98 per 1000 hours match play. Acute strain/sprain and impact injuries had the highest injury incidence and prevalence (3–4/1000 hours and 6–8%). Age was noted as clinically significant for injury surveillance. Players over the age of 24 years had an increased injury incidence (6 per 1000 hours compared to 4 per 1000 hours), higher prevalence (11% v 8%) and a greater severity (27 days lost v 24 days) per injury than players under the age of 24 years. Moore et al (2014) also noted that 63% of all match injuries were sustained during a tackle.  This is the only published study reporting injury surveillance in Welsh Rugby however, this was only published as an abstract and it is difficult to determine if these are meaningful differences.  More recently, Rafferty et al (2018) presented injury surveillance data in professional rugby union in Wales in the four seasons between 2012/13 and 2015/16, however this study only reported concussive head injuries.

When match related injuries in professional rugby union are compared across injury surveillance studies, Welsh professional (international) rugby union has a higher injury incidence per 1000 hours of match exposure (figure 2.0). The time between these individual studies may be a confounder given that players' physiological characteristics have changed between 2002 and 2011. Professional Rugby Union players were found to be taller, heavier and younger with statistically significant increases noted amongst fly halves, props and back row forwards (Fuller et al, 2013).

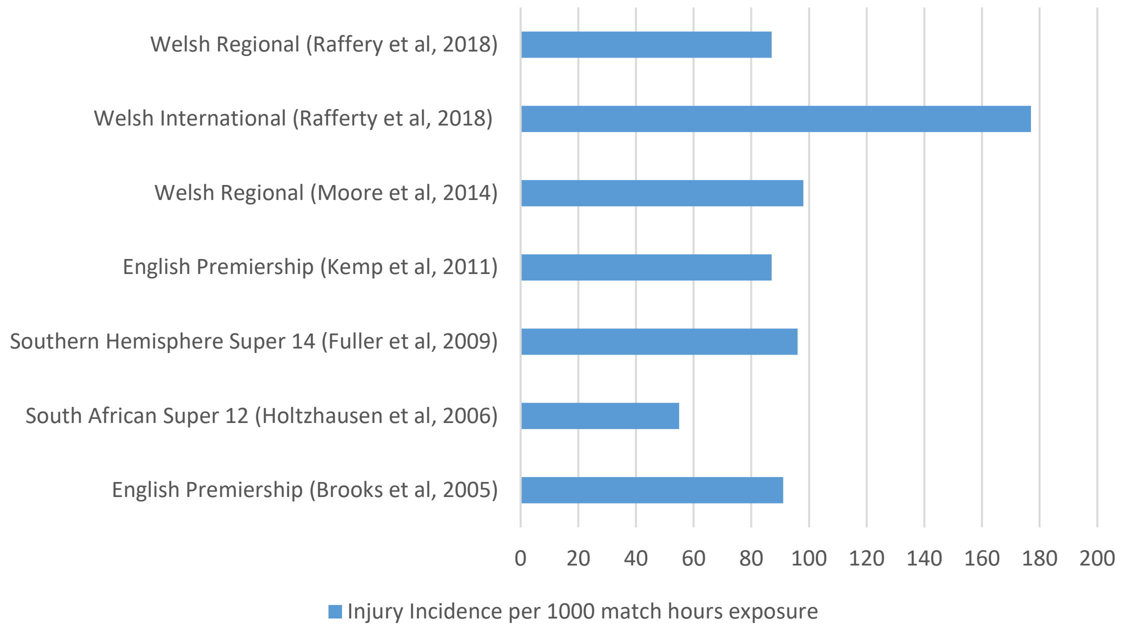



Figure 2.0. A comparison of match injury incidence in professional world club rugby.

While injury surveillance is the start of the process as shown earlier in figure 1.1, the process is cyclical and ongoing. Once the extent of the injury problem has been established, the cause, risk factors and mechanism can be explored. This developed understanding allows practitioners to address the specific issues and intervene where required. During or on completion of the intervention, an assessment of the effectiveness is determined. This can be delivered by comparing injury data to previous seasons.

## 2.3 Systematic Literature Review Intrinsic: Risk Factors for Sports Related Groin Pain & Exercise Programmes for Groin Injury Reduction

The purpose of this literature review is to examine the intrinsic risk factors for sports related groin pain (SRGP) and examine the evidence for exercise based interventions in reducing SRGP in athletic populations.

### 2.3.1 Systematic Literature Review Method

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al, 2009) were followed. PRISMA is an evidence-based minimum set of items for reporting in systematic reviews and meta-analyses. PRISMA focuses on the reporting of reviews evaluating randomised trials, but can also be used as a basis for reporting systematic reviews of other types of research, particularly evaluations of interventions. As such it was considered the most appropriate methodology for this systematic review.

### 2.3.2 Literature Search

A comprehensive electronic search of the literature in Medline, PubMed, SPORTDiscus, Web of Science and Cochrane was conducted on 28 October 2017 without date restrictions. Details of the search strategy are presented in appendix 1.

Various combinations of the following keywords were utilised and adapted for each database; ‘adductor’, ‘groin’, ‘pelvis’, ‘hip’, ‘pain’, ‘athletic injury’, ‘sport injury’, ‘prevention’, ‘exercise’, ‘reduction’. All potential references were imported in to RefWorks (ProQuest LLC) and duplicates were removed. Titles and abstracts were screened by the author. The full text of each eligible published study was then examined according to the inclusion and exclusion criteria and reference lists of included studies were manually searched to identify further articles for inclusion.

### 2.3.3 Study Selection

Inclusion criteria were 1) studies of any research design; 2) investigation of an exercise intervention for either the treatment or prevention of groin/hip/adductor pain and/or injury in sports performers; 3) studies investigating all sexes, ages, types and levels of sport were considered eligible for inclusion. Groin pain was defined according to the Doha agreement meeting on terminology and definitions of groin pain in athletes (Weir et al, 2015). According to the Doha agreement, groin pain is classified as either 1) adductor-related, iliopsoas-related, inguinal-related, pubic-related; 2) hip-related or 3) other causes of groin pain in athletes. Both acute and chronic onset of groin pain and injury were included in this review. Exercise is defined according to the American College of Sports Medicine (ACSM) as a type of physical activity consisting of planned, structured, and repetitive bodily movements done to improve and/or maintain one or more of the components of physical fitness (ACSM, 2013. pp.2). Study participants were considered sports performers if they participated in any sport listed under the Medical Subject Heading ‘sports’ (including human activities, leisure activities, recreational activities and sports).

### 2.3.4 Data Extraction

The author completed a risk of bias assessment on each included article using the Downs and Black Scale (Downs and Black, 1998), which was modified to remove non-applicable items for cohort and case-control study designs. The Downs and Black checklist has been developed for the reporting of methodological quality of both randomised controlled trials and the modified version was used for the cohort and case-control series. The modified Downs and Black checklist consists of fifteen items for a maximum of 16 points. The risk of bias of studies meeting >75% of the applicable criteria was considered low, 60-74% considered moderate and <60% was considered high, as previously used in published literature (Charlton et al, 2017). Papers were considered high quality studies (HQS) if they scored 10 or above and low quality studies (LQS) if they scored below 10 (Barton et al, 2012). The results of the modified Downs and Black Quality Index is provided in table 2.1.

### 2.3.5 Best-Evidence Synthesis

The level of evidence of exercise interventions for the prevention and treatment of groin pain was evaluated using previously published methods which are modifications to the van Tulder et al (2003) and Reurink et al (2014) method. The level of the strength of evidence was defined as “strong” if it is consistently identified in two or more studies, and a greater than or equal to 75% of all contributing findings. The definition of “moderate” was used if it was consistently identified in two or more studies, and greater than 50% of all contributing findings. Finally, “conflicting” was used to identify inconsistency in two or more findings.

The Oxford Centre of Evidence-Based Medicine (OCEBM) Levels of Evidence was utilised to determine the hierarchical levels of evidence according to the type of research question with the highest level of evidence (level 1) pertaining to systematic reviews with the specific criteria and the lowest level of evidence (level 5) being ‘mechanism-based reasoning’ (Phillips et al, 2001).

### 2.3.6 Exercise Reporting Standards

The standard of exercise intervention reporting was evaluated using the Consensus on Exercise Reporting Template (CERT): Explanation and Elaboration Statement (Slade et al, 2016). The checklist consists of 16 items for a maximum score of 19 points and has been designed for use in the evaluation of reporting of exercise programmes across all study designs for exercise research. Studies which satisfied greater than 75% of criteria were considered to have a high level of reporting standard, 60-74% moderate and studies that satisfy less than 60% of criteria were deemed to have poor exercise reporting standards (Charlton et al 2017). The exercise intervention of the studies was deemed to be reproducible if it met the following criteria: 1) detailed description of the exercise, 2) detailed description of the sets/repetitions and frequency and 3) detailed description of the intensity and method of external load application as well as the method of progression.

## 2.4 Results of Systematic Literature Review

The electronic search identified 1953 records which were screened. Thirty five full text articles were screened for eligibility against the inclusion criteria. Sixteen articles were excluded, and 19 articles were included in the systematic review. The flow chart of this process is presented in figure 2.1 and an overview of the included studies is given in table 2.0

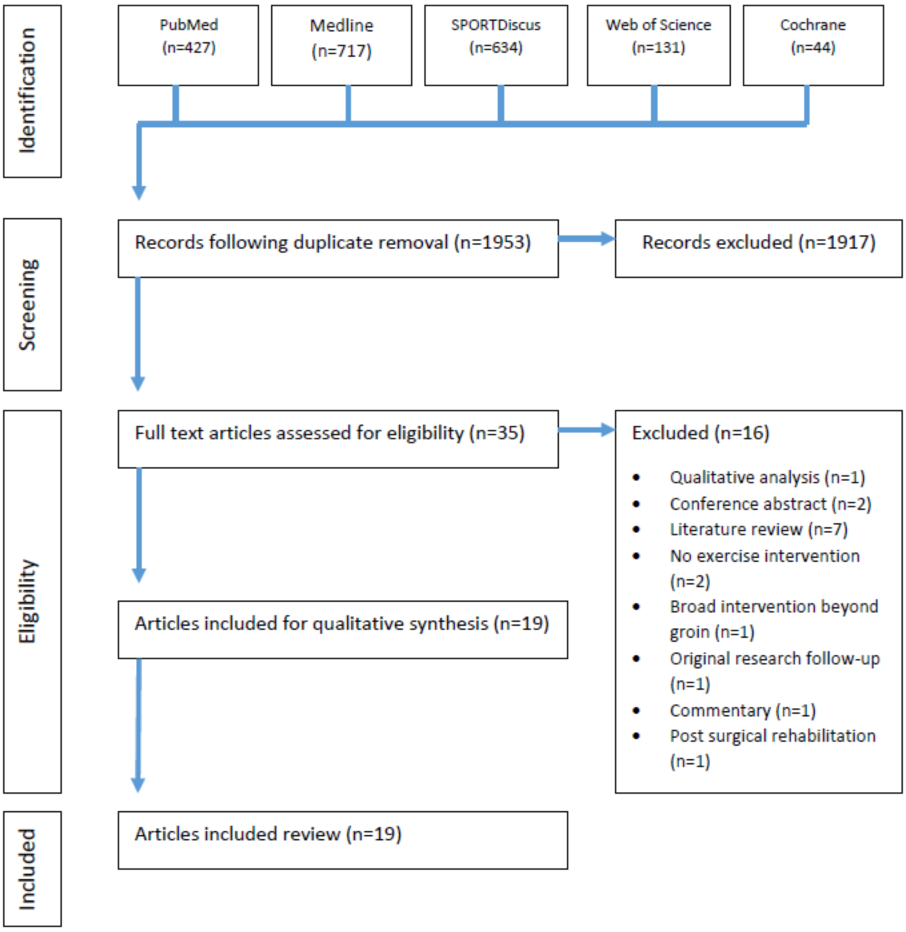



Figure 2.1 Flow chart of the selection process for the systematic literature review

Table 2.0 General overview of the included studies

| Reference | Type of Study | Terminology | N (Injury:Control) | Level of sport |
|---|---|---|---|---|
| **Prevention studies** | | | | |
| Hölmich et al. 2010 | Cluster Randomised Control Trial | Groin injury | 524:453 | Soccer (amateur) |
| Tyler et al. 2002 | Prospective | Adductor strain | 33:25 | Ice Hockey (professional) |
| **Intrinsic Risk Factor Studies** | | | | |
| Arnason et al. 2004 | Prospective cohort | Groin strain | 17:281 | Icelandic Soccer (elite and first division) |
| Cowan et al. 2004 | Retrospective case-controlled | Long standing groin pain | 10:12 | Australian Rules Football (elite or sub elite) |
| Crow et al. 2010 | Prospective | Groin injury | 12:12 | Australian Rules Football (elite) |
| Emery & Meeuwisse 2001 | Prospective cohort | Groin strain injury | 204:1088 | Canadian National (ice) hockey league (professional) |
| Engebretsen et al. 2010 | Prospective cohort | Groin injury | 51:457 | Football (amateur) |
| Ibrahim et al. 2007 | Prospective | Adductor strain | 8:79 | Australian Rules Football (professional) |
| Jansen et al. 2010 | Retrospective case-controlled | Adduction-related groin pain | 42:23 | Various (amateur) |
| Malliaris et al. 2009 | Retrospective case-controlled | Groin pain | 10:19 | Australian Rules Football and Soccer (elite) |
| Mens et al. 2006 | Retrospective case-controlled | Adduction-related groin pain | 44:44 | Various (amateur) |

| | | | | |
|---|---|---|---|---|
| Mohammad et al. 2014 | Retrospective case-controlled | Osteitis Pubis | 20:20 | Football (level not stated) |
| Morrissey et al. 2012 | Retrospective case-controlled | Chronic groin Pain | 9:9 | Football (amateur) |
| Nevin & Delahunt 2013 | Retrospective case-controlled | Long-standing groin pain | 18:18 | Gaelic Football (club level) |
| O'Connor 2004 | Prospective | Groin injury | 21:72 | Australian Rugby (Professional) |
| Thorborg et al. 2014 | Cross sectional | Adductor-related groin pain | 21:16 | Football (elite and sub-elite) |
| Tyler et al. 2001 | Prospective | Adductor strain | 8:37 | Ice hockey (professional) |
| Verrall et al. 2005 | Retrospective case-controlled | Chronic groin injury | 47:42 | Australian Rules Football and Soccer (professional) |
| Verrall et al. 2007 | Prospective cohort | Chronic groin injury | 4:25 | Australian Rules Football (professional) |

Table 2.1 Appraisal of the quality of research included in the systematic literature review

| **Item number** | **1** | **2** | **3** | **5*** | **6** | **7** | **10** | **11** | **12** | **15** | **16** | **18** | **20** | **21** | **25** | **Total (/16)** | **Study Quality** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Prevention studies** | | | | | | | | | | | | | | | | | |
| Holmich et al. 2010 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 14 | HQS |
| Tyler et al. 2002 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 7 | LQS |
| **Intrinsic Risk Factor Studies** | | | | | | | | | | | | | | | | | |
| Arnason et al. 2004 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 15 | HQS |
| Cowan et al. 2004 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 13 | HQS |
| Crow et al. 2010 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 10 | HQS |
| Emery & Meeuwisse 2001 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 10 | HQS |
| Engebretsen et al. 2010 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 12 | HQS |
| Ibrahim et al. 2007 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 10 | HQS |
| Jansen et al. 2010 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 10 | HQS |
| Malliaris et al. 2009 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 12 | HQS |
| Mens et al. 2006 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 13 | HQS |
| Mohammad et al. 2014 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 8 | LQS |
| Morrissey et al. 2012 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 10 | HQS |
| Nevin & Delahunt 2013 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 9 | LQS |
| O'Connor 2004 | 0 | 1 | 1 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 12 | HQS |
| Thorborg et al. 2014 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 15 | HQS |
| Tyler et al. 2001 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 10 | HQS |
| Verrall et al. 2005 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 10 | HQS |
| Verrall et al. 2007 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 9 | LQS |

(1) Clear aim/hypothesis, (2) clear outcome measures, (3) clear participant characteristics, (5) clear principal confounders, (6) clear study findings, (7) estimates of random variability provided, (10) probability values provided, (11) invited participants representative of entire
population, (12) participants prepared to participate representative of entire population, (15) attempt to blind outcome measures, (16) no data dredging, (18) appropriate statistical tests, (20) valid and accurate outcome measures, (21) appropriate case–control matching, (25) adequate adjustment for confounding variables, D&B Downs and Black Quality Index, HQS high-quality study, LQS low-quality study

### 2.4.1 Hip Range of Movement

*Hip abduction range of movement*

A number of studies have examined the role of soft tissue flexibility in groin injury risk. Arnason et al (2004) studied risk factors for injury in a large group (n=306) of Icelandic footballers. As part of their preseason battery of tests, hip flexibility was measured. Hamstring, hip flexor and rectus femoris muscle length were measured from photographs taken of test positions. Hip adduction flexibility was measured using a double arm goniometer. Players were followed over the 4 month competitive season and injury surveillance data was recorded. Players in the top two leagues of Icelandic football reported a match incidence of groin injuries of 2.7/1000hours exposure and 0.2/1000 training hours. Using multivariate logistic regression analysis, Arnason et al were able to demonstrate that a lower ROM in hip abduction was found to be a significant predictor variable for a new groin strain (P = 0.05). Tyler et al (2001) also measured hip abduction ROM (adductor flexibility) using a goniometer in their study on 47 professional ice hockey players across two seasons. Hip flexor flexibility was also measured with a goniometer. Tyler et al's results conflict those of Arnason, with no significant difference in preseason hip adductor flexibility between the players who subsequently sustained adductor strains (46.3°± 10.3°) and the uninjured players (45.8° ± 11.0°) (P = 0.92). Tyler also noted there was no significant difference in adductor flexibility between the injured side (46.3° ± 10.3°) and the uninjured side (46.3°± 9.2°) (P =0.69). No differences were noted for hip flexor flexibility either. Thorborg et al (2014) compared 28 footballer with adductor related groin pain to 16 healthy controls in a cross-sectional study. They found no significant difference in the adductor flexibility of the healthy footballers (47.5° ± 5.9°) compared to the adductor related groin pain group (45.0° ± 7.2°, P= 0.27).

Malliaris et al (2009) examined strength and flexibility measures in 29 junior elite football players (AFL and Soccer). Hip abduction was assessed using the bent knee fall-out (BKFO) test, where the patient lies in supine in the crook lying position with the feet together. The patient allows one knee to drop outwards towards the plinth and the therapist measures the height of the knee to the plinth to the nearest 0.5cm. Hip internal rotation ROM was measured with the patient in prone, with the knees together and flexed to 90º. Each foot was allowed to drop out to the side and a bubble inclinometer used to measure the range of hip internal rotation by measuring the angle of the tibial shaft. Finally, hip external rotation was measured with the patient in supine and the test leg positioned off the edge of a plinth. The patient had their shin passively moved outwards and upwards until end of range was achieved and a bubble inclinometer was again used to record ROM. Malliaris et al reported acceptable inter and intra-tester reliability for BKFO and hip internal rotation (ICC >0.75) however the supine external rotation measured reported an lower inter-rater ICC of 0.64. Results showed no significant difference in hip flexibility measures between players with groin pain and the control group.

*Hip extension range of movement*

Two studies have examined the relationship between hip extension flexibility and sports related groin pain. Arnason et al (2004) collected data on soccer players. Hip extension was measured from photos taken of participants performing a hip extension test (Thomas Test). This prospective study did not find any significant association between hip extension flexibility and the incidence of sports related groin pain. The second study was completed by Thorborg et al (2014). Again this study, although retrospective in its data collection, used the same Thomas Test position and reported similar findings. Results showed no significant relationship between hip extension flexibility and sports related groin pain (SRGP mean=13.7° ± 4.9°, control mean=14.5° ± 2.7°, P= 0.57).

*Hip rotation range of movement*

One study has examined the relationship between hip rotation range of movement and chronic groin injury. Verrall et al (2005) examined Australian rules footballers with and without pubic bone stress injury and chronic groin injury (any groin pain symptomatic for more than 6 weeks). They used a standard goniometer to record passive hip internal and external range of movement with the participants positioned in supine, with hips and knees flexed to $90^{o}$. The range of movement was reported as the sum of the dominant and non-dominant leg range of movement. Of the 89 participants, 47 reported chronic groin injury symptoms. Verrall et al's (2005) results show that the sum of dominant and non-dominant internal rotation and external rotation were reduced in chronic groin pain patients compared to the control group (P<0.05). It is interesting to note that the sum of rotation movements in the dominant and non-dominant leg were considerably less than normative data. Normative values for internal rotation tested in the same position as Verrall's protocol should be between 30-40$^{o}$, and external rotation normative values are placed between 40-60$^{o}$ (Neumann, 2010). In this study the sum of the dominant and non-dominant leg internal rotation was reported as 36.7° ± 10.1$^{o}$, and external rotation as 55.2° ± 10.5$^{o}$ for the chronic groin pain group. The control group also reported ranges of movement well below those expected (internal rotation = 41°.4 ± 11.8$^{o}$; external rotation = 60.3° ± 9.7$^{o}$).

Ibrahim et al (2007) used a prospective design to examine the relationship between hip rotation ROM in 120 professional Australian footballers at the end of one season, comparing those players who sustained an adductor strain (n=8) with those who did not. They found a significant relationship between dominant and non-dominant leg preseason hip total ROM between injured and injured players. The rotation range of movement values were recorded in the same supine position used in Verrall's study (dominant leg mean hip ROM = 53.3$^{o}$ in control group versus 44.7$^{o}$ in injured players; non dominant leg mean hip ROM = 56$^{o}$ in the control group versus 53.7$^{o}$ in injured players). Standard deviations were not provided. They concluded that decreased total hip rotation ROM may be considered an aetiological factor in the occurrence of adductor strain in male professional soccer players.

### 2.4.2 Adductor Muscle Strength

Four high quality prospective studies have identified a significant reduction in adductor muscle strength as predisposing factor of SRGP (Engebretson et al, 2010; Crow et al, 2010; O'Connor, 2004; Tyler et al, 2001). Several studies, using differing methods show no significant association between adductor strength and groin injury.

Engebretsen et al (2001) examined intrinsic risk factors in 508 footballers, from 31 teams across 3 divisions of Norwegian soccer. Players were tested for adductor strength in the supine position with the hip and knee extended and a hand held dynamometer placed 5cm proximal to the medial malleolus. Players completed 2 maximal contractions with 10seconds rest in between with highest value for each leg recorded. Engebretsen et al reported using a similar protocol to Krause et al (2007), however all of Krause's protocols involved patients in the side lie position. Also Krause' participants completed 3 test repetitions with 1 minute recovery. Engebretsen et al reported a coefficient of variation of 19.6%. They classified players as either weak or not weak but failed to report their cut off values and criteria for this grouping. Their results showed players classified as having weak adductor strength measured in the supine position are at a 4 times greater risk of developing a groin injury than non-weak players.

Crow et al (2010) examined hip adductor strength preceding the onset of groin pain in elite junior football players (n=86). Hand held dynamometry was used citing a previously published measurement error of 2% in spinal cord injury patients (Sisto and Dyson-Hudson, 2007) rather than their own reliability data. Participants were positioned in supine, with the knees flexed and feet flat on the plinth. This protocol had previously been shown to have good intra-rater (ICC = 0.79, 95% CI = 0.65-0.87) and inter-rater (ICC = 0.79, 95% CI = 0.64 – 0.88) however this study was conducted on 200 females patients with posterior pelvic pain post pregnancy rather than an athletic population. Crow et al (2010) concluded that a reduction in hip adductor strength of 11.75 ± 2.5% from baseline preceded the onset of groin pain.

O'Connor (2004) examined groin injuries in professional Australian rugby league players (n=100). Players had no previous history of groin injury. Adductor strength was assessed using isokinetic dynamometry. Peak torque, work, power, endurance ratio and peak torque ratio were all calculated and incidence of groin injuries was monitored over 2 seasons. Isokinetic testing was completed with the player in a side lie position and the dynamometer placed at the proximal knee. A discriminating factor between injured and non-injured players was the non-dominant leg angle of peak torque during adduction 3.66 rads.sec$^{-1}$ and decreased adductor muscle strength at an angular velocity of 2.08 rads.sec$^{-1}$.

Tyler et al (2001) examined the association between hip strength and flexibility and adductor strain injury in professional ice hockey players. Seventeen out of an initial cohort of eighty one players completed the two year study. Tyler et al used hand held dynamometry to assess hip strength. The adductors were assessed in a side lie position, with knee extension and the leg adducted to twelve inches off the plinth. This would be considered an inner-range test position. A figure (bar graph) depicts the adduction strength though the exact figures (± SE) are not presented in the text (Figure 2.3). It appears that the average preseason adductor strength of non-injured players is higher than injured players, though it should be noted that only 8 players sustained adductor strains over the course of the study compared to 39 non-injured players. This study is also criticised for incorrectly reporting injury surveillance data, presenting incidence per 1000 exposures rather than per 1000 hours of exposure making comparisons to other studies difficult.

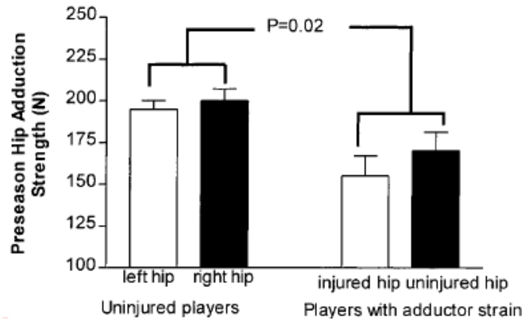



Figure 2.3 Mean (± SE) preseason adductor hip strength (Tyler et al, 2001).

Thorborg et al (2014) examined eccentric and isometric hip adduction strength in 21 male soccer players with groin pain compared to a control group of 16 players. Using hand-held dynamometry participants were eccentrically and isometrically tested for adductor strength, using ‘break’ and ‘make’ tests respectively. They do not describe the test positions used within their protocol (e.g. side lie or supine) only that lever length was measured and strength was reported as torque, adjusted for body weight (Nm/Kg). A significant difference was noted in adduction eccentric (break) hand-held dynamometry test between the groin pain and control groups (2.47 ± 0.49 versus 3.12 ± 0.43 Nm/Kg, P= <0.001) however no significant difference was noted in isometric (make) adductor strength test (1.83 ± 0.59 versus 1.87 ± 0.43, P= 0.841).

Emery and Meeuwisse (2001) completed a prospective cohort design study examining risk factors for groin injury in ice hockey. Nine hundred and ninety five NHL players were tested for peak hip adductor isometric strength using a hand held dynamometer during preseason. Participants were positioned in supine, with the knees flexed to 90$^{o}$ and feet flat on the plinth and aligned with the anterior superior iliac spine. The hand-held dynamometer was placed over the distal vastus medialis.

Players completed a maximal adduction against the pads of the hand-held dynamometer. Each test was completed 5 times and the peak torque was recorded. Lever arm length was measured from the centre of the inguinal canal to the superior border of the patella on the right leg, allowing peak adductor torque to be calculated. A pilot study revealed excellent test-retest reliability (ICC= 0.95) within this study. Mean peak adductor torque was measured as 203.26 Nm (95% CI = 199.61-207.31Nm). There was no association found between peak isometric adductor torque and injury.

Mohammad et al (2014) examined isokinetic imbalance of the hip muscles in soccer players with ‘osteitis pubis’. Twenty male soccer players with osteitis pubis were compared to twenty asymptomatic players. Isokinetic dynamometry was assessed using a Biodex system. Participants were required to stand with their back to the dynamometer, the pad was placed approximately mid-thigh, and participants completed 2 sets of 5 repetitions abduction/adduction at a velocity of 2.1 $rad.sec^{-1}$ with 60sec rest between sets. Peak torque was recorded (Nm) and normalised to weight (Nm/Kg). Results showed no significant association between the asymptomatic and ‘osteitis pubis’ group for adductor or abductor muscle strength (P= 0.891 and 0.887 respectively).

A number of other studies have reported changes in adductor strength using a squeeze test protocol. This involves placing either a hand held dynamometer (HHD) or a sphygmomanometer between the knees and asking the patient to perform an isometric squeeze. Where a sphygmomanometer is used it is pre-inflated to between 10 and 40mmHg before placing the device in between the knees. The sphygmomanometer records a bilateral adductor isometric strength score in mmHg. Unlike the isokinetic dynamometer it is a quick and inexpensive method of measuring adductor strength, however is not able to detail unilateral comparisons. Three high quality studies and one low quality study has utilised the adductor squeeze with the hip positioned in 45º flexion.

Jansen et al (2010) used a HHD to assess adductor isometric strength in 45º flexion. Their results showed no significant difference in transverse abdominis or internal obliquus muscle thickness and isometric hip adduction strength in competitive amateur athletes with longstanding adductor related groin pain and controls.

Malliaris et al (2009) examined hip flexibility and strength measures in soccer players with groin pain. They assessed adductor strength using a sphygmomanometer pre-inflated to 10mmHg and placed between the knees of participants who were in a supine crook-lying position. Adductor strength was measured at 0º, 30º and 45º of hip flexion. The study reports acceptable intra tester (ICC at 0º = 0.81, 30º = 0.91 and 45º = 0.94) and inter-tester reliability (ICC at 0º = 0.80, 30º = 0.82 and 45º = 0.83). Results stated that footballers with groin pain had a significant force reduction on adductor squeeze (P=<0.05) and that this test is adequate for discriminating between football players with and without groin pain.

Mens et al (2006) examined the role of a pelvic bind for reducing groin pain in recreational athletes. In this study isometric hip adduction force was used as a dependent variable was measured by placing the participants in supine with the knees flexed to 90º and the feet flat on the plinth. Strength was measured by placing a HHD on the medial aspect of the knee and was held in place by the tester. Participants then performed three isometric squeezes without a warm up and the best score was recorded. Results from their study show recreational athletes with groin pain have an increase in isometric adductor strength when wearing a pelvic belt bind.

Nevin and Delahunt (2013) also used an isometric adductor squeeze against a sphygmomanometer to compare 18 Gaelic footballers with groin pain to a control group. Their protocol used a pre-inflated cuff (10mmHg) and positioned players in supine crook lying with hips flexed to 45º. Players completed 3 maximal efforts with 2 minutes rest in between. Results showed a significant difference in isometric adductor squeeze strength between the control group (269 ± 25mmHg) and Gaelic footballers with groin pain (202 ± 36 mmHg, P=<0.01).

### 2.4.3 Abductor Muscle Strength

Three studies have examined the role of abductor muscle strength (Thorborg et al, 2014; Malliaris et al, 2009; O'Connor, 2004).

One prospective, high quality study by O'Connor (2004) provided limited evidence of a decrease in abductor muscle strength as a risk factor for groin injuries in their professional rugby league cohort. Peak torque during isokinetic testing of the abductors in angular velocity of 0.52 $rad.sec^{-1}$ made a significant contribution to discriminating between players with and without groin injury.

Malliaris et al (2009) completed a retrospective study with 29 junior elite football

(Australian rules and soccer) players. Hip abduction strength was measured using a hand-held dynamometer with the player lying in supine in hip and knee extension. The dynamometer was placed 5cm proximal to the lateral joint line of the knee. A one-off effort of 3 second maximal abduction was recorded to the nearest 0.1Kg and the distance from the greater trochanter to the dynamometer was also recorded (i.e. the moment arm). Intra-rater reliability for this protocol was deemed to be good (ICC = 0.81-0.84, 95% CI = 1.7 – 1.8). Inter-rater reliability was moderate (ICC = 0.58-0.73, 95% CI = 2.5-3.1). No significant difference was found between hip abduction strength scores in groin pain and asymptomatic players [e.g. right leg abduction strength 13.3 (± 2.0 Nm) in control group (n=19) versus 13.1 (± 2.5 Nm) in groin pain group (n=10), (P=0.84)].

Thorborg et al (2014) examined eccentric and isometric hip adduction strength in 21 male soccer players with groin pain compared to a control group of 16 players. Isometric hip abduction strength was also measured with a hand-held dynamometer placed 5cm above the lateral malleolus using a long lever make test protocol. Lever length was measured and strength was reported as torque, adjusted for body weight (Nm/Kg). It is not known whether the patient was placed in supine or side lie. There was no difference in isometric hip abduction scores between the control and test groups (1.98 ± 0.34 Nm/Kg v 1.89 ± 0.25 Nm/Kg, P= 0.395).

### 2.4.4 Adductor to Abductor Strength Ratios

One prospective, high quality study by Tyler et al, (2001) identified that ice hockey players with reduced adduction: abduction strength ratios were at risk of developing a subsequent adductor muscle strain. Using HHD and a 'break' test protocol in the side lie position, ice hockey players with adductor: abduction strength ratios of 80% or less were 17 times more likely to sustain an adductor muscle strain. Of the eight players who were injured in the following season, an average adductor: abductor ratio of 78% was observed preseason. This study has however been criticised for its inadequate and incomplete presentation of data (Kloskowska et al, 2016).

Another retrospective high quality study by Thorborg et al (2014) completed isometric HHD testing in the long lever position. Their results show that 21 elite and sub elite male soccer players with adductor-related groin pain (ARGP) had an adductor: abductor strength ratio of 0.92 ± 0.23, whilst the control group of 16 players without ARGP had an adductor: abductor strength ratio of 0.99 ± 0.18. This difference was non-significant ($P = 0.353$).

One other study has used isokinetic dynamometry to establish adductor: abductor ratios. Mohammad et al (2014) compared the peak torque of 20 male soccer athletes with Osteitis Pubis to 20 control soccer athletes. Results showed an adductor: abductor peak torque ratio at 120º $sec^{-1}$ (2.1 $rads.sec^{-1}$) of 1.45 ± 0.93 for the Osteitis Pubis group versus 1.40 ± 0.53 for the control group. This difference was also non-significant ($P = 0.793$).

One study has utilised surface EMG to examine the differences in hip muscle activation of male soccer athletes with and without chronic adductor injury. Morrissey et al (2012) examined Gluteus Medius and Adductor Longus activation during a standing hip flexion task in 9 male soccer athletes with a history of chronic adductor injury and compared them to a matched control group. A significant reduction in muscle activation ratios was observed in the chronic adductor injury group during both standing and moving elements of the hip flexion task (P<0.001). During the stance phase, the test group showed an average reduction in Adductor Longus activation of 20% and Gluteus Medius activation of 40-50%. During the movement phase, Gluteus Medius: Adductor Longus activation ratios were reduced by an average of 50-60% in the test group. This was primarily caused by a reduction in Gluteus Medius activation. It is difficult to comment further on these ratios as only a log scale of the ratio was presented.

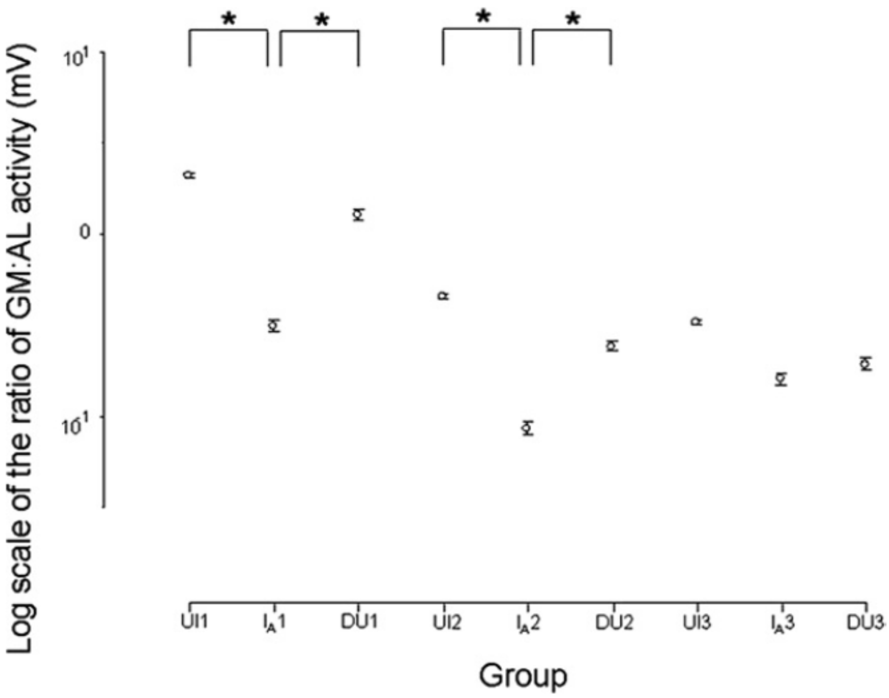



Figure 2.4. Results from Morrissey et al (2012) demonstrating the ratio of Gluteus Medius to Adductor Longus activation during the stance phase, plotted on a log scale for three data sets: UI (uninjured group), IA (injured group) and DU (dominant leg of uninjured group). The three phases of movement represented are onset (1), middle (2) and end (3).

### 2.4.5 Hip Flexor Strength

Hip flexor strength has also been examined as a potential intrinsic factor for hip and groin injury. Mohammad et al, (2014) have provided limited support for this in their retrospective, low quality study in male soccer players. This study used isokinetic dynamometry at $120^{o}.sec^{-1}$ (2.1 $rads.sec^{-1}$) through an $110^{o}$ range of hip extension to flexion. Results showed that soccer players with Osteitis Pubis (n=20) had a mean peak torque for hip flexion of 156.45 Nm ± 25.49 whereas the control group (n=20) produced a mean peak torque of 113.12 ± 23.76. They concluded an increase in hip flexor strength was associated with sports related groin pain.

Thorborg et al (2014) examined adductor related groin pain in 40 elite and sub elite male soccer players. They measured isometric hip flexor strength in the traditional position and also in a modified Thomas test position with a HHD. No significant difference was observed between players with and without ARGP in either the traditional or modified Thomas test position ($P$ = 0.737, and $P$ = 0.518 respectively).

### 2.4.6 Hip Extensor Strength

Hip extension strength has only been examined by one study in relation to groin pain. Mohammad et al, (2014) used isokinetic dynamometry to examine the difference in hip extension strength between soccer athletes with and without Osteitis Pubis. Results show no association between hip extensor strength and Osteitis Pubis (Osteitis Pubis group average Peak Torque = 174.75 Nm ± 24.85 vs control group = 170.33 ± 12.47; $P$ = 0.381). This is the only study to examine both hip flexion and extension in groin pain athletes.  There is therefore little evidence for hip flexor: extensor strength ratios in groin pain athletes. In this study, the Osteitis Pubis group had an average flexor: extensor ratio of 0.90 Nm ± 1.02 versus 0.66 Nm ± 1.91 in the control. This was significantly different (*P* = 0.002).

### 2.4.7 Other Strength Markers as Intrinsic Risk Factors for Groin Pain

The literature has also briefly examined the role of knee and abdominal muscle strength in sports related groin pain. O'Connor (2004) examined groin injuries in 100 professional rugby league players in Australia. Knee extension and flexion were measured using isokinetic dynamometry in a seated position at speeds of 1.04 $rad.s^{-1}$ ($60^o.sec^{-1}$), 3.14 $rad.s^{-1}$ ($180^o.sec^{-1}$) and 5.22 $rad.s^{-1}$ ($300^o.sec^{-1}$). Results showed non-significant differences between extension peak torque of the dominant and non-dominant legs in the non-injured and injured groups. A non-significant difference was also reported for knee flexion peak torque. Discriminant analysis of their findings however did show that peak torque bilateral deficits of knee extension at 3.14 $rad.sec^{-1}$ ($180^o.sec^{-1}$) made a significant contribution to discriminating between injured status groups. A weaker, but still significant contribution was also found with the non-dominant adductor: hamstring peak torque ratio.

The thickness of abdominal stabilising muscle Transverse Abdominis has also been examined in relation to longstanding adductor related groin pain. Jansen et al (2010) used ultrasound to examine the thickness of Transverse Abdominis in 40 competitive amateur male athletes. The right sided Transverse Abdominis thickness was significantly smaller in longstanding adductor related groin pain athletes when compared to the control group (left sided groin pain athletes = 4.0 ± 0.82mm, *P* < 0.001; right sided groin pain athletes = 4.3 ± 0.64mm, *P* = 0.015; versus control group = 4.9 ± 0.9mm). Cowan et al (2004) examined the activation of transverse abdominis, internal and external obliquus and rectus abdominis in 10 elite and sub-elite Australian Football League (AFL) players with long-standing groin pain. Using fine-wire electromyography, results showed a significantly delayed onset of activation of the transverse abdominis muscle in groin pain players during an active straight leg raise, compared to the control group ($P < 0.05$). No such difference was found in the obliquus or rectus abdominis muscles.

### 2.4.8 Effectiveness of Exercise Interventions on Reducing the Incidence of Sports Related Groin Pain

Whilst a significant body of literature surrounding potential predisposing factors for SRGP exists, very limited evidence supports the effectiveness of exercise interventions for the prevention of groin pain in athletes. Only two prospective studies have been published. Hölmich et al (2010) examined the effect of six basic adductor and abductor strengthening, balance and iliopsoas lengthening exercises on groin injuries in football players. During the 1997-1998 season, 120 clubs were invited to participate. Unfortunately only 44 teams completed the study, with 907 players submitting complete data. This was significantly short of the 80 required from Power calculations. Nevertheless, 44 teams were cluster randomised in to a Prevention Group (PG, n = 477, median age 24.49 years) and a Control Group (CG, n = 430, median age = 24.62 years). The prevention programme detailed specifically how the exercises should be performed, including the sets and repetitions of each exercise prescribed. Club physiotherapists were given training on the correct performance of the intervention and 'spot checks' were undertaken regularly to ensure that the program was completed as per instructions. The intervention took a total of 13 minutes to complete. Despite its' simplicity, the intervention has been criticised for its lack of external load, and lack of progression/periodisation of the program (Charlton et al, 2017). The intervention was designed to work as part of the football warm up, and as teams trained between 2 and 4 times per week for a period of 33 weeks, it can be assumed that this represents the frequency of intervention sessions. All adductor related injuries were assessed by the clubs Physiotherapist and were recorded for the purposes of the study, using a definition set by the Sports Injury Consensus Group (Fuller et al, 2006). This study has received commendation for its reproducibility, given the intervention detail provided. However, results show no significant effect of the intervention on injuries (P = 0.18) despite a reduction in risk of groin injury of 31% in the intervention group.

The second study to examine the effectiveness of exercise interventions on adductor muscle strains is by Tyler et al (2002). In their study, 58 professional ice hockey players over the 1999-2000 and/or 2000-2001 seasons underwent preseason screening of adduction: abduction strength ratio, as measured using the break test HHD protocol described earlier. Players identified as having an adduction: abduction ratio below 80% participated in the intervention. The intervention is listed below in table 2.2:

- Warm-up
  - Bike
  - Adductor muscle stretching
  - Sumo squats
  - Side lunges
  - Kneeling pelvic tilts
- Strengthening program
  - Ball squeezes (legs bent to legs straight)
    - Different ball sizes
  - Concentric adduction with weight against gravity
  - Adduction while standing with a cable column or elastic resistance
  - Seated adduction machine
  - Standing with involved foot on sliding board and moving in the sagittal plane
  - Bilateral adduction on sliding board and moving in the frontal plane (that is, bilateral adduction simultaneously)
  - Unilateral lunges with reciprocal arm movements
- Sports-specific training
  - On ice kneeling adductor pull togethers
  - Standing resisted stride lengths with a cable column to simulate skating
  - Slide skating
  - Cable column crossover pulls
  - Clinical Goal: Adduction strength at least 80% of the adduction strength

Table 2.2 Adductor muscle strain injury prevention programme from Tyler et al (2002).

This intervention includes isometric, concentric and eccentric strengthening of the adductors, concentric and eccentric strengthening of the abductors, abdominal strengthening and balance exercises. Unfortunately, the prevention programme does not detail the exercise prescriptions including duration, frequency, sets, repetitions, external load and progressions so it is difficult to reproduce this protocol. Despite the lack of specifics, the results from this study show significant reduction in the number of adductor strains (11 in previous seasons, versus 3 in the study period, $P < 0.01$), and a significant reduction in incidence per 1000 player games (3.2/1000 in previous seasons versus 0.71/1000 in the study period $P < 0.05$). As mentioned earlier, incidence should be expressed per 1000 player hours as a more reliable indicator of player exposure, rather than player games. The difficultly using player games is that it may not give an accurate reflection of the players total time of exposure and it makes comparing studies very difficult. Total time on ice during hockey games may vary significantly from player to player and cannot be assumed to be equal. In a typical 60 minute game a player may be on ice anywhere between 15-20 minutes, comprised of shifts ranging between 30-80seconds (Montgomery, 1988). There is also a difference in on-ice time between positions, for example defensemen typically have longer shifts than forwards (Roczniok et al, 2016). In Tyler et al's study, players were involved with 88 games in the 1999-2000 season, and 86 games in the 2000-2001 season. This method of reporting incidence could mean a player game difference of 1320 hours versus 1700 hours. It also does not take in to consideration the training exposure, as players in the Tyler et al study participated in 136 training sessions in season 1, and 139 training sessions in season 2. Training time is not recorded and adductor strains are widely acknowledged to have an insidious onset that could potentially be related to fatigue and increased exposure.

### 2.4.9 Summary of Literature Review

*Adductor muscles*

There appears to be strong evidence of an association between adductor muscle strength and sports related groin pain, with a decrease in adductor strength associated with an increased risk of groin pain. Four prospective studies (Crow et al, 2010; Tyler et al, 2001; Engebretsen et al, 2010; Emery and Meeuwisse, 2001) reported adductor muscle weakness prior to the onset of groin pain. Crow et al, 2010 specifically reported decreased adductor muscle strength 2 weeks before the onset of groin pain. Two weeks is insufficient to consider a weakness due to muscle atrophy and so authors have proposed a potential neural inhibition mechanism for the reduction in strength rather than true muscle weakness. This evidence may persuade clinicians to include adductor strengthening in their preseason and in-season strength and conditioning programmes. Six studies reviewed here have examined the relationship between hip abduction range of movement and sports related groin pain. Of these six, only Nevin and Delahunt (2013) report a significant association however this study is retrospective and low in quality.

*Abductor muscles*

There is an association between decreased hip abduction strength and sports related groin pain. This association was however, only observed in prospective but not retrospective studies suggesting that any weakness in hip abductor strength precedes groin pain but is quickly resolved, for example through rehabilitation. This may encourage practitioners to include hip abduction strengthening during preseason and in-season programmes.

*Hip Adductor to Abductor Ratio*

Four studies were reviewed here that considered adductor to abductor ratios or gluteus medius to adductor longus ratio. Only one high quality, prospective study by Tyler et al, 2002 concluded that in the players who sustained an adductor strain, the preseason adduction-to-abduction strength ratio was lower on the side that was subsequently injured compared with the uninjured side (P = 0.011). Tyler et al (2002) highlight that players with an adductor-to-abductor ratio below 0.80 are 17 times more likely to sustain an adductor strain. The remaining three studies failed to find a significant relationship between adductor-to-abductor strength ratio or muscle activity and injury risk.

### 2.4.10 Methodological Considerations of Included Studies

To summarise the literature presented in this review, despite the significant body of literature available on sports related groin pain (SRGP) a number of methodological limitations are noted. Studies published before the Doha consensus (Weir et al, 2015) differ dramatically in the diagnostic terminology used. Terms such as long-standing groin pain (Cowan et al, 2004), adduction-related groin pain (Jansen et al, 2010), chronic groin pain (Morrissey et al, 2012) and adductor-related groin pain (Thorborg et al, 2014) have all been used. These studies have also used subtle differences in the diagnostic criteria. For example Morrissey et al (2012) and Malliaris et al (2009) use an anatomical location of pain alongside passive and resisted movement tests to differentiate adductor related pain from hip joint pain. Cowan et al (2004), Jansen et al (2010) and Thorborg et al (2014) used palpation of painful area with resisted hip adduction as part of their study inclusion criteria.

Some studies collected their injury data prospectively, meaning the sample was monitored for a set period of time (in some case up to two seasons e.g. Tyler et al, 2002), and injuries were recorded as they happen. Some other studies relied on retrospective injury data (e.g. Cowan et al, 2004; Jansen et al, 2010; Nevin and Delahunt, 2013). This method relies heavily on memory recall bias where participants are required to self-report previous history and is discouraged by Van Mechelen et al (1987).

Studies were often ambiguous about the side/limb tested. There was a lack of methodological clarity in some studies regarding whether testing had occurred on the dominant or non-dominant limb, left or right side, moving or non-moving limb, injured or uninjured side (e.g Ibrahim et al 2007; Arnason et al, 2004; Tyler et al, 2001). Studies by Verrall and colleagues (2005 & 2007) were very clear in their measurement of dominant and non-dominant sides. As a result a number of reviews have recommend the measurement of dominant and/or non-dominant limbs (Kloskowska et al, 2016).

Measurement protocols varied across the studies reviewed for both range of movement and strength assessments. Strength measurements incorporated hand-held dynamometres (e.g. Thorborg et al, 2014; Jansen et al, 2010; Mens et al, 2006), aneroid sphygmomanometres (Malliaris et al, 2009; Nevin and Delahunt, 2013) and one study used an isokinetic dynamometer (Mohammad et al, 2014). The protocols for each testing device were not identical for example, the HHD studies examined isometric (Jansen et al, 2010) and eccentric contractions (Thorborg et al, 2014). The differences in methodologies makes comparisons and data pooling difficult. Where HHD was used, the reliability of measurements by the assessor was not reported in 5 studies (E.g. Cowan et al, 2004; Tyler et al, 2001; Morrissey et al, 2012; Engebretsen et al, 2010; Verrall et al 2005). The reliability of the testers must be reported for the reader to have any confidence in the measures, results and conclusions drawn.

Some studies failed to provide the minimum anthropometric data expected such as height, weight and age (E.g. Crow et al, 2010; Emery and Meeuwisse, 2001; Engebretsen et al, 2010; Tyler et al, 2001; Verrall et al, 2005). Such omissions compromise the readers’ ability to apply findings to their own practice and limits the external applicability of the research.

The heterogeneity of literature, particularly methodologically, makes it difficult to compare study results. Studies differ in injury definitions, risk factors considered and the measurement of those risk factors. Studies also lack clarity regarding their inclusion and exclusion criteria. Population characteristics are limited in some cases to age, playing experience and basic anthropometric data- omitting information on training stimulus (e.g. GPS data, number of training days and intensity, matches played, training and match surface etc). These methodological issues inhibit study reproducibility and limit the application of the study findings.

Studies have highlighted a need for subjective, objective and functional outcome measures in a field based population (Ryan et al, 2013). Rugby union studies are of particular importance given the incidence of hip/groin injuries. A study that tests the same group of players through a playing season and compares the results in relation to hip/groin injury status would confirm or negate SRGP injury risk factors in a rugby union population (Ryan et al, 2013). In response, this study will prospectively follow one professional rugby union team in a field based setting, across four competitive seasons.

### 2.4.11 Development of Test Battery

Based upon the findings of the systematic literature review, a battery of tests will be developed for the first intervention season. A simple battery of 6 tests will be used to assess the players' dominant leg pre and post fatigue, elicited by a maximal running task (Yo-Yo IR Level 1). The six tests selected are adductor squeezes at $0^o$, $60^o$ and $90/90^o$, side lie long lever adduction and abduction using a hand-held dynamometer, and prone hip extension using a hand-held dynamometer.

From the systematic literature review there is strong evidence for the association between adductor strength and sports related groin pain. A quick and easily administered method for assessing adductor strength is the adductor squeeze using a pre-inflated (10mmHg) sphygmomanometer. This test will be administered in three positions – at $0^{o}$, $60^{o}$ and in the $90/90^{o}$ test position to encompass adductor magnus and gracilis; adductor longus; and pectineus and adductor brevis respectively (Neumann, 2010a). This equipment is readily available in medical rooms in the sporting setting and inexpensive. Whilst some studies have measured adductor squeeze in one position (most commonly in the $60^{o}$ or crook lying position), no study has measured the adductor squeeze in all three positions. A number of other studies reviewed measured adductor strength using hand held dynamometry (e.g. Emery & Meeuwisse, 2001; Cowan et al, 2004, Tyler et al, 2001). Hand-held dynamometry is also a quick and easily administered method for assessing adductor strength though studies do not often report their reliability coefficients. A side-lie long lever position will be used to maximise lever length and also standardise the degree of hip extension. Players can also stabilise themselves easily in side-lie to provide a safe position for applying the test force.

There is limited evidence for the association between abduction strength and sports related groin pain, and it has been overlooked as an intrinsic risk factor for LPH injuries. This test battery will include a hand-held dynamometry assessment of abductor strength in the long lever, side lying position similar to Tyler et al (2001) protocol to examine the role of abductor weakness may have in LPH injuries.

From the systematic literature review, there is little evidence for the role of hip extension weakness in sports related groin pain. The only study reviewed measured hip extension strength using isokinetic dynamometry. However, given the triplanar nature of the adductors and the attachment of adductor magnus to the ischial tuberosity (see chapter 1.6 for more detail), it seems logical to examine the role of the hip extensors in LPH injuries. Again, HHD will be used with reported reliability coefficients. The player will be tested in prone to ensure a safe and stable position for the application of the test force.

## 2.5 Players Perceptions of Sports Injury Reduction Programmes

As mentioned previously, musculoskeletal injuries are common in rugby union. Injury reduction strategies that aim to modify injury risk have been promoted for various reasons. Such justifications of reduction strategies include: player welfare, the financial cost of injury to the club, and player, and team success. Injury prevention programmes in sport have typically involved a one-size-fits-all, en-masse approach to prevention. Such programmes have classically implemented a defined set of exercises, prescribed to everyone at the same dose to reduce the incidence of a specific injury or injuries. Examples of this include the FIFA 11+ and the Prevent Injury and Enhance Performance Programme (PEP) and have already been discussed.

One limitation of all injury prevention studies is poor adherence from the participants. Studies report superior preventative results with higher compliance to the exercises

(Gagnier et al, 2013; Hägglund, Atroshi, Wagner, & Waldén, 2013). Compliance is an important issue in order to optimise the effect of injury reduction programmes, whereas lack of compliance might be the limiting factor for the overall success of injury prevention (Alentorn-Geli et al., 2009). Any intervention done to reduce injuries in professional team sport will not reach its full potential unless it is correctly implemented and maintained over a long period of time (O'Brien & Finch, 2016). The two prevention studies identified from the earlier systematic literature review do not cite their compliance (Hölmich et al, 2010; Tyler et al, 2002). A number of other generic injury prevention programmes implemented in sport have reported compliance data ranging from 19.4% of participants completing more than 30 sessions (Engebretsen et al, 2008) to less than 6% of soccer players completing 50% or more injury reduction sessions (Kiani et al, 2010). Occasionally studies report 100% compliance without defining this statistic (Longo et al, 2012). Despite evidence for the effectiveness of injury reduction programs, McCall, Dupont, and Ekstrand (2016) showed that the top 33 teams of the UEFA Elite Club Injury Study perceived the players' adherence with injury prevention, as well as the quality of execution, as limiting the effect of such interventions.

Very few studies have investigated the players' perceptions of injury reduction programmes (as targeted end users) in order to understand motivation to participate in programmes or other factors that may affect adherence. Only two studies have examined the recipients of one-size-fits-all exercises aimed at reducing injuries in sport. Finch et al (2014) used an end of season survey to examine community Australian Football players' experience of using a 20 minute neuromuscular injury prevention warm up, versus a control group warm up. Results showed that participants in the neuromuscular injury prevention group (n=192) found the exercises less physically challenging than their normal warm up, more enjoyable and potentially of more benefit than their previous injury prevention programme. Recommendations for future injury prevention programmes included reducing the time, increasing the intensity and range of exercises and promoting the programmes injury prevention benefits to the participants (Finch et al, 2014). Kristiansen & Larsson (2017) examined eight elite professional soccer players lived experience of injury prevention programmes using open ended interviews. Three key themes emerged as being central to the players feeling empowered to engage with injury prevention. Firstly, being part of a performance environment; the injury prevention programme was only deemed meaningful when the medical staff, coaches and the entire organisation supported it. The effect and relevance of any programme was perceived to be reduced when only the medical department supported it. Secondly, players reported the need for an individualised approach to injury prevention. Players stated that they felt a lack of respect from medical staff when programmes were not individualised as players felt they knew what was best for their body, however they were happy to help medical staff with information in order to develop the best programme for them. This is in direct contrast to the majority of injury prevention programmes that provide all participants with a generic set of injury prevention exercises for a generic injury (e.g. lower limb). Finally, players described strong personal ambition as a key motivator for participating in injury prevention programmes. Players discussed the opportunity to play for a larger club. They stated that doing exercises to prevent injury and enhance performance allowed them to do better than their peers thus maximising individual performance and increasing the opportunity to play at a more prestigious club and achieve more success. This was noted as an important reason to engage with prevention programmes.

Very few studies relating to injury prevention in sport use social and behavioural science theories even though they could be used to enhance the preventative effect of the intervention (McGlashan & Finch, 2010). Chan & Hagger (2012) proposed an integrated framework for injury prevention intentions. This framework integrates two theories: the Theory of Planned Behaviour (TPB) and Self-Determination Theory (SDT) (Keats, Emery, & Finch, 2012). The TPB was originally proposed by Ajzen (1985) and describes how people's engagement in volitional behaviours is a function of three belief-based factors; Attitudes (subjective evaluations of that behaviour), Social or Subjective Norms (perceived social appropriateness of the behaviour) and Perceived Behavioural Control (one's perceived confidence in their ability to engage in the behaviour), as overviewed in figure 2.5. These three constructs predict the individuals' *intention* to perform that behaviour in the future. If the participant views it positively, believes that significant others think they should perform it and believes they have the confidence and ability to perform it, the participant will be motivated to engage in the activity.

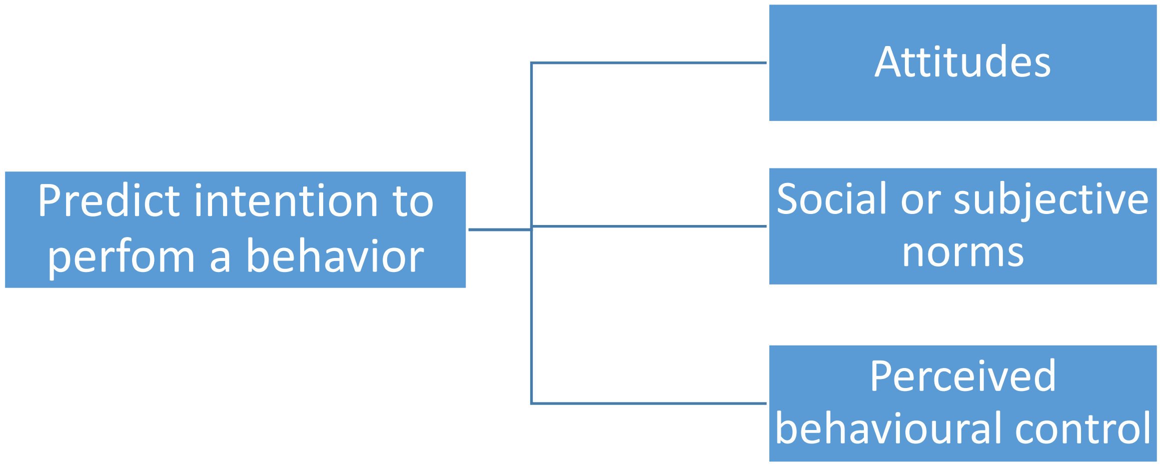



Figure 2.5 Theory of Planned Behaviour (Ajzen, 1985).

Deci and Ryan (1985) proposed the SDT (figure 2.6). It states that the quality of motivation (i.e. the reason an individual will engage in a particular activity) will predict their behavioural commitment and persistence. Motivation will either be autonomous, where the motivation is driven by ones sense of volition, self-satisfaction or intrinsic values, or controlled, where the motivation is determined by the participants' experience of pressure, external demands or the defence of the individual's self-esteem or ego. According to Keats et al (2012) intrinsic motivation will be present if the task is freely performed (autonomy), if the person is able to master the task (competence) and if it is considered meaningful to the individual (relatedness).

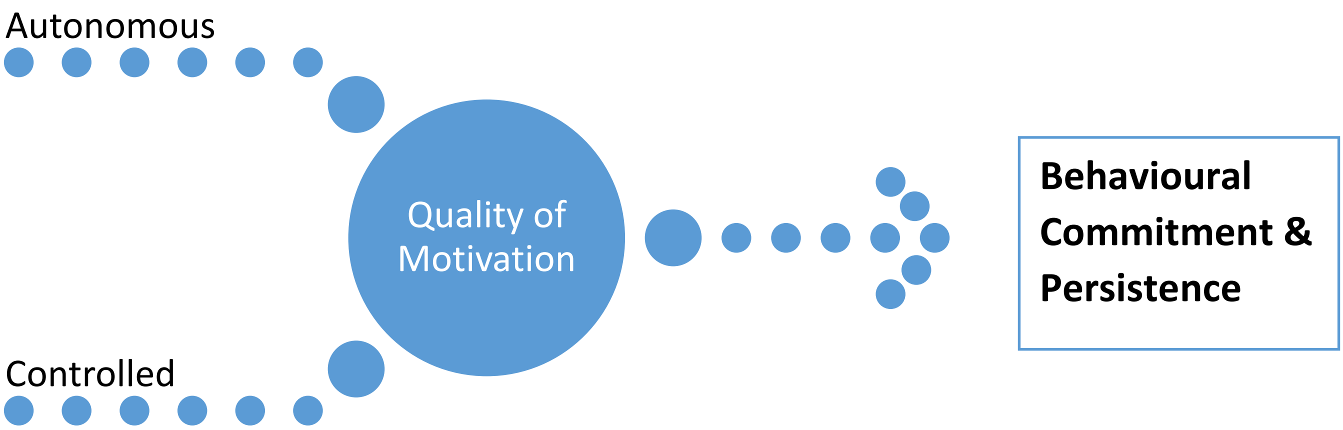



Figure 2.6 Self Determination Theory (Deci and Ryan, 1985).

The integrated framework of these two theories, proposed by Chan & Hagger (2012) states that the intention to perform a behaviour is based upon proximal and distal predictors and is presented in figure 2.7. Proximal predictors include subjective or social norms, attitude and perceived behavioural control. Distal predictors include autonomous motivation and controlled motivation.

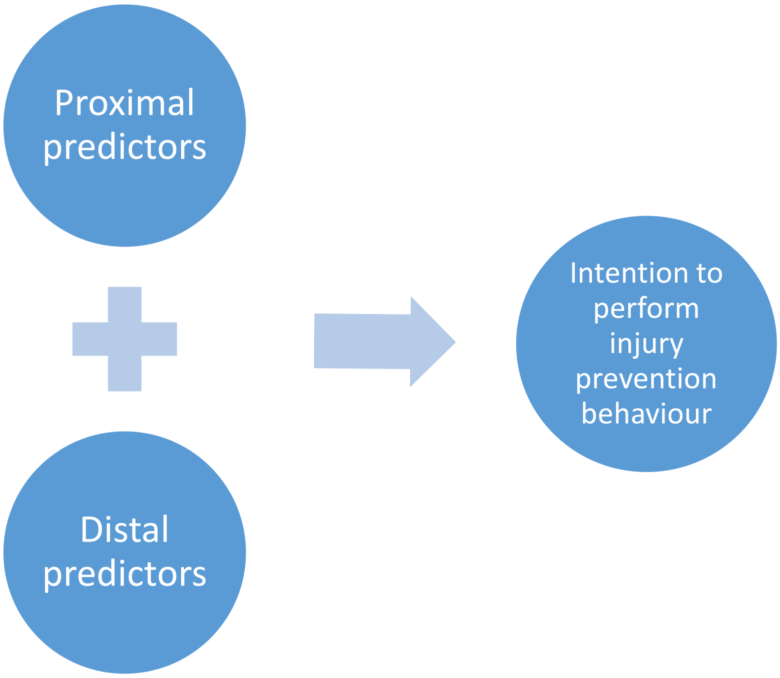



Figure 2.7 Integrated Framework for Injury Prevention Behaviours (Chan and Hagger, 2012).

This integrated framework has been applied to a number of health behaviours including physical activity, dieting and breastfeeding (Hagger & Chatzisarantis, 2009). In the field of injury prevention, it was first used to predict injury prevention behaviours among police officers (Chan & Hagger, 2011). Results here showed a positive effect of autonomous motivation on the intention of officers to engage with occupational injury prevention. This effect was significant and fully mediated by attitude and subjective norm. Within sport, Chan & Hagger (2012a) examined the injury prevention experiences of 533 elite athletes. Within this study, the integrated framework showed that the autonomy of SDT and the three variables of the TPB positively predicted intentions of injury prevention. In contrast to their hypothesis a more controlled motivation from the SDT was also positively linked to the intentions, however not as effectively as autonomous motivation (Chan & Hagger, 2012a). To date, no study has yet examined the lived experience of professional rugby union players with injury reduction programmes.

## 2.6 Summary of Chapter

Injury surveillance practices are clearly defined in rugby union. Any study that wishes to examine the effectiveness of any injury reduction strategy needs to carefully consider adhering to the current consensus on the reporting of injury incidence, injury severity and prevalence. These guidelines are strictly adhered to in the subsequent chapters. Following the systematic literature review, an understanding of the current literature surrounding the risk factors for sports related groin pain and the effectiveness of exercise interventions for the prevention of groin pain have been gathered including an appreciation of the limitations of current knowledge. These have informed both the screening and intervention implemented in the subsequent chapter. Following this chapter, the next phase of the study has ensured the Doha consensus statement (Weir et al, 2015) and Rugby Injury Consensus Group (Fuller et al, 2007) are strictly followed. A prospective design is employed as recommended in the literature reviewed (Tyler et al, 2002 and Van Mechelen et al, 1987). The dominant side is measured as per recommendations by Verrall et al (2005 & 2007), and Kloskowska et al, (2016). Strength is the primary screening outcome using a hand held dynamometer (Thorborg et al, 2014; Jansen et al, 2010; Mens et al, 2006) and aneroid sphygmomanometer (Malliaris et al, 2009; Nevin and Delahunt, 2013) however unlike previous studies, the testers reliability in using these methods is also reported and a comparison made between baseline and fatigue measures. Exercise interventions are reported in accordance with CERT guidelines (Slade et al, 2016). Basic anthropometric data (such as age, height and weight) is also reported to facilitate comparisons across studies.

Phase 2 of this study questions players', as service end users about their perceptions and preferences in injury reduction programmes to target increased compliance (Chapter 3).  As has already been mentioned, studies report superior preventative results with higher compliance to the exercises. Without consulting the players themselves, how can we ensure their motivation to engage with injury reduction behaviours?

# Chapter 3 Methodology

## 3.0 Introduction to the Chapter

The purpose of this chapter is to present the research paradigm used within this thesis and to subsequently detail the methodologies used within the three phases of this study across the four competitive seasons. An overview of the research process used within this study is represented in figure 1.12.

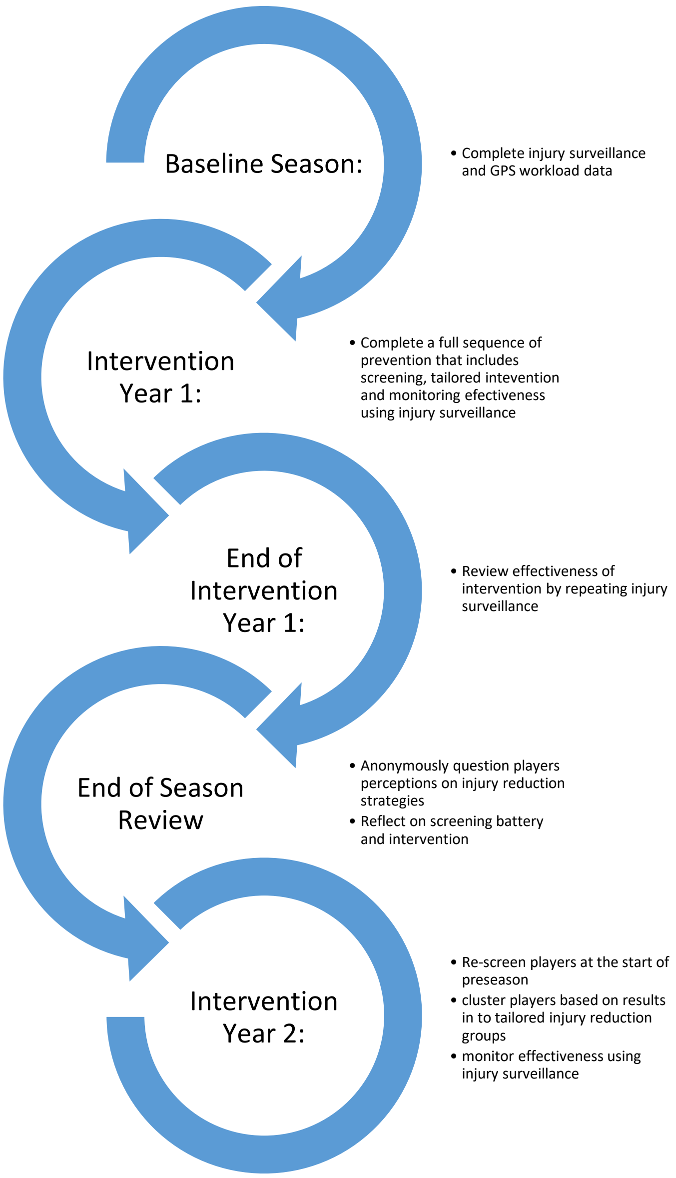



Figure 1.12 Overview of the research process.

## 3.1 Ontology and Epistemology

Research activity is dichotomised by two concepts: ontology and epistemology. Ontology is defined by Crotty (2003) as the study of being. It is concerned with what kind of world is being investigated, the nature of existence and structure of reality. Guba and Lincoln (1989) state that the ontological assumptions are those that respond to the question ‘what is there that can be known?’ or ‘what is the nature of reality?’ Within ontology, there are two main positions; objectivism and subjectivism. Objectivism asserts that social phenomena and their meanings have an existence that is independent of social actors. It implies that social phenomena and the categories that are used in everyday discourse have an independent existence that is separate from actors (Bryman and Bell, 2011). Subjectivism however asserts that social entities are created through the perceptions and actions of social actors. Social entities have a reality that is experienced, performed and enacted (Bryman and Bell, 2011). In essence, the objectivist position believes that there is a single, external reality and the subjectivist position believes that reality is subjective, internal and may be multiple in nature.

Epistemology is a way of understanding and explaining how we know what we know (Crotty, 2003). Epistemology is also ‘concerned with providing a philosophical grounding for deciding what kinds of knowledge are possible and how we can ensure that they are both adequate and legitimate (Maynard, 1994). Positivism and interpretivism are two contrasting epistemological positions. Positivism refers to the school of thought that the only true or valid form of knowledge is that which is scientific and where the principles and methods of the natural sciences can be used.

Positivism is associated with objective, tangible knowledge (Gratton and Jones, 2004). Positivism does not take into consideration intangible concepts related to the freedom to act in a number of ways, such as feelings and emotions. These concepts form the basis of the interpretivist approach. Complex issues such as emotions and feelings cannot simply be reduced to numerical values and therefore are often measured in terms of words, statements and observations, which are then interpreted by the researcher to uncover meanings (Gratton and Jones, 2004). In this regard, the interpretivist position asserts that knowledge is perceived and varies from person to person (Cohen, Manion and Morrison, 2007). In addition to the positivist and interpretivist epistemological approaches, a post positivist approach has been proposed. Phillips and Burbules (2000) state that post positivism refers to thinking after positivism and challenges the traditional notion of the absolute truth of knowledge. Knowledge that is developed through a post positivist lens is based upon careful observation and measurement of the objective reality that exists in the 'real world' (Cresswell, 2003).

The research approach can either be inductive or deductive. An inductive research approach 'involves the search for pattern from observations and the subsequent development of explanations or theories for those patterns' (Bernard, 2011). Conversely a deductive research approach is concerned with 'developing a hypothesis (or hypotheses) based on existing theory, and then designing a research strategy to test the hypothesis' (Wilson, 2010). From the research approach a research method will emerge. Quantitative research methods are based in the natural sciences and is an approach used for testing objective theories by examining the relationship between variables (Cresswell, 2014). Conversely, qualitative research methods are typically based in the social sciences and is an approach for exploring and understanding the meaning individuals or a group ascribe to a social or human problem (Cresswell, 2014). Methodologies can also be mixed. Mixed method research involves a combination of procedures where two or more data collection techniques and forms of analysis are employed and both contribute to the final results (Tashakkori & Teddlie, 1998).

The net that contains the researchers' epistemological, ontological and methodological premises may be termed the 'research paradigm' (Guba, 1990). The researcher is bound within this net of ontological and epistemological premises (Bateson, 1972) and it forms the basic set of beliefs that guide the researchers' actions (Guba, 1990). Hitchcock and Hughes (1995) suggest that 'ontological assumptions give rise to epistemological assumptions; these in turn, give rise to methodological considerations; and these in turn, give rise to issues of instrumentation and data collection' (pp. 21).

Within medical research paradigms, there is a heavy bias towards objectivism, positivism, deductive approaches and quantitative methods (Zeinaloo, 2004). However, the results of such methods are often not implemented in clinical practice (Zeinaloo, 2004). Within injury prevention research, cited in chapter 1, O'Brien et al (2018) presented the Team-sport Injury Prevention (TIP) cycle. This model highlights that practitioners working at the injury prevention 'coalface' would be better served by a model that is simple, directly applicable to the teams' specific context and acknowledges real-world implementation challenges. Perhaps the real issue here is that the research basis for injury prevention in sports is required to employ evidence based practice (EBP). EBP is about solving clinical problems. Montori and Guyatt (2008) described a shift in medical paradigms early in the 1990's towards a concept of EBP, which was in direct contrast to the traditional paradigm of medical practice. EBP places lower value on unsystematic clinical experience and pathophysiologic rationale and suggests that interpreting the results of clinical research requires a formal set of rules, and places a lower value on authority than the traditional medical paradigm (Montori and Guyatt, 2008). At the centre of EBP is the nature of evidence and two fundamental principles. Firstly, EBP suggests a hierarchy of evidence to guide clinical decision making and secondly, that evidence alone is never sufficient to make a clinical decision. 'Decision makers must always evaluate the benefits and risks, inconvenience and costs associated with alternative management strategies and in doing so, consider their patients' values and preferences (Haynes et al, 1996). A traditional medical research paradigm would not consider the patients perceptions in this process at all. Objective ontologies, positivist epistemologies, deductive approaches and quantitative research methods can only advance this field so far. The true difficulty with any injury reduction research is the successful implementation of the injury reduction programme and the compliance of the participants. This can only be achieved through a mixed methods approach where player perceptions are explored using a subjectivist ontology, interpretivist epistemology, inductive research approaches and qualitative research methods. The methodological approach for this study will therefore combine both paradigms in a mixed-method approach.

Cresswell (2014) highlights four philosophical worldviews; postpositivism, constructivism, transformative and pragmatic. The postpositivism view has been mentioned earlier this chapter. Constructivists believe that individuals seek understanding of the world in which they live and work, which is subjective, varied and multiple. The transformative worldview holds that research inquiry needs to be intertwined with politics and the political change agenda, so that an action agenda for reform emerges with the ability to change the lives of both the participants and the researcher and the institutions in which they work or live. Finally, the pragmatic worldview is concerned with the consequences of actions. It is a problem centred approach to research that is concerned with applications and solutions to problems (Patton, 1990). Instead of focusing on methods, the researcher emphasises the research problem and uses all available approaches to understand the problem (Rossman and Wilson, 1985). This study has employed a pragmatic worldview in order to solve an injury burden problem in one professional rugby union team.

Insider action research (IAR) is a relatively new concept. Initially introduced in 2001, the phrase appeared to give voice to a practice that was struggling for legitimacy and which hitherto had not been framed in a manner that facilitated its place in the action research literature (Coughlan and Holian, 2007). Action research has been traditionally defined as an approach to research that is based on a collaborative problem-solving relationship between researcher and client, which aims at both solving a problem and generating new knowledge (Coughlan, 2003). The term insider researcher is used to describe a situation where the researcher is a part of the topic being investigated (Given, 2008). Undertaking IAR implies a process of inquiry as a permanent member of an organisational system (Adler, Shani, & Styhre, 2004; Coghlan & Brannick, 2009), requiring both an organisational and academic perspective. This is especially acute when the IAR researcher is a professional, with the moral, ethical and professional requirement to actively prioritise the wellbeing of service users, and with the ongoing need to maintain a positive relationship to professional peers, at the same time as undertaking the research study (Nylan et al, 2016). According to Coughlan (2007) insider action research is an exciting, demanding and invigorating prospect that contributes considerably to researchers' own learning and contributes to the development of the systems in which we work, we live, and with which we have affiliations. The insider action researcher is an interventionist, as contrasted with insider research which focuses on observation and analysis only and does not aim to change anything (Alvesson 2003). Insider action research is characterised by the researcher being immersed experientially in the situation (Evered and Louis, 1981; Flyvbjerg, 2001). Such researchers have the opportunity to acquire 'understanding in use' rather than 'reconstituted understanding' (Coughlan, 2003). There are a number of challenges to performing IAR, these are preunderstanding, role duality and managing organisations politics. Preunderstanding refers to 'such things as people's knowledge, insights and experience before they engage in a research programme' (Gummesson, 2000). Whilst preunderstanding brings the researcher closer to the data, it also has its disadvantages. The IAR researcher may assume too much and so not probe as much as if they were outsiders or ignorant of the situation (Coughlan, 2007). Role duality between the organisational and researcher roles can also be a challenge. The IAR researcher may encounter role conflict and find themselves 'caught between loyalty tugs, behavioural claims and identification dilemmas' (Coughlan, 2007). Managing organisational politics emphasises questioning that may be considered subversive. As mentioned previously in the previous chapters there is a need for injury reduction research to consider a field based population and the translation of injury prevention research in to real world meaningful reductions in the injury burden. A study that utilises the insider action researcher approach will be high in ecological validity and as such, may be better placed to implement an effective injury reduction programme.

## 3.2 Phase 1: Baseline Season Injury Surveillance and Intervention Season 1

Phase 1 of this study represents a complete action research cycle, and a complete sequence of prevention. The first stage will involve following the team for a complete season and monitoring injury surveillance data to ‘establish the extent of the LPH injury problem’. From there, step two will use the systematic literature review to examine the aetiology for LPH injuries. Step three will involve implementing the screening and injury reduction programme developed from an understanding of the aetiology. Finally, step 4 will examine the effectiveness of the intervention based upon prospective injury surveillance data.

### 3.2.1 Participants

Twenty-eight male professional regional rugby union players (age 24.4 ± 3.8 years; stature 181.6 ± 6.8 cm; mass 105 ± 13.08 kg) fit and available at the start of the season 2 preseason volunteered to take part in this study (backs n= 11, forwards n=17). Seven players had suffered a time-loss LPH injury in the previous 12 months however all players were currently asymptomatic of LPH pain and in full training. The remainder of the squad (n=22) were excluded by absence at the start of preseason (e.g. international rugby duties at Senior and Under 20s level) or injuries that were unsuitable for testing. All players gave written informed consent to participate in the study, which had been approved by the University of Wales, Trinity Saint David Research Ethics Committee.

### 3.2.2 Research Design

Phase 1 of this research project employed a prospective, case controlled design. Figure 3.0 displays the research study overview.

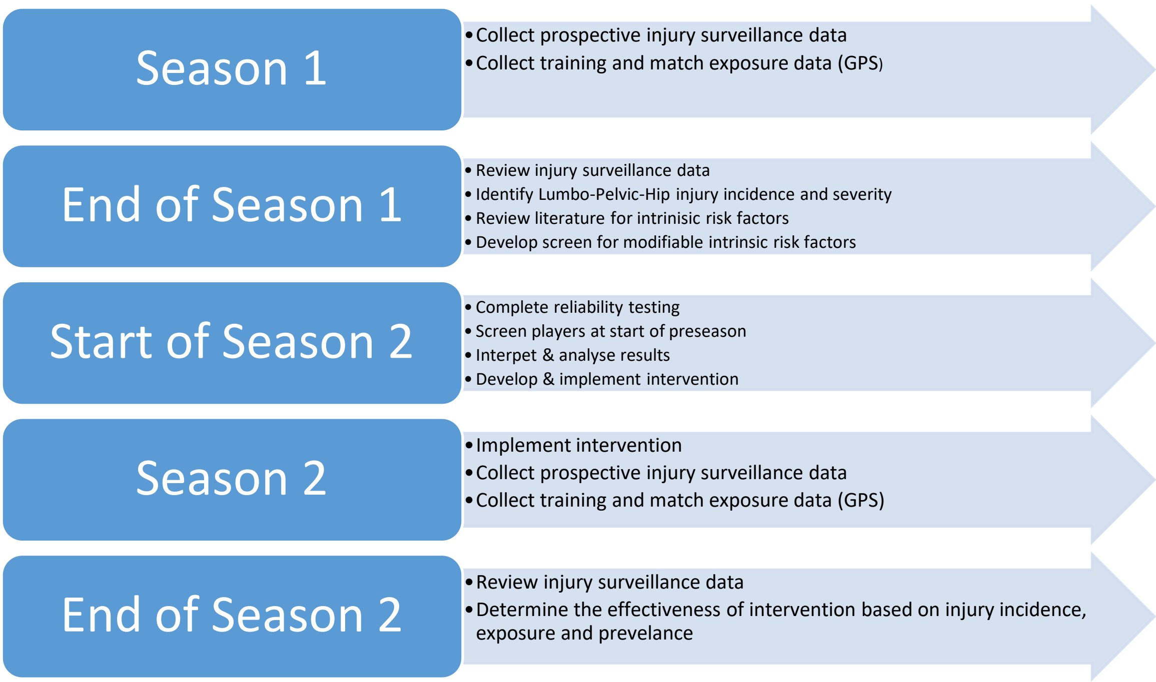



Figure 3.0 Overview of phase 1 of the research process including timeline.

### 3.2.3 Protocol

In the experimental season the team completed 35 competitive matches in the domestic league and European cup competitions. In comparison the team played 34 games across three competitions in the previous season. GPS data for both seasons were compared.  Average distance covered per week in training and games for forwards and backs, and average metres per min in training and games for forwards and backs were comparable across the two seasons.

Table 3.0 Summary of team training and match GPS data.

| | | Season 1(Baseline) | | Season 2 (Intervention) | |
|---|---|---|---|---|---|
| | | Forwards | Backs | Forwards | Backs |
| Training | Average distance covered per week (m) | 10738±1404 | 14245±1810 | 10768±1062 | 13946 ± 2032 |
| | Average training metres per minute | 38.03±2.58 | 56.99 ±2.6 | 47.08±3.5 | 55.4±3.1 |
| Match | Average distance covered per game | 5926±471 | 6470.8±603 | 4541±572 | 6957±641 |
| | Average Metres per minute | 66.6±4.61 | 80.3 ±5.02 | 68.1±3.1 | 78.12±3.9 |

Table 3.1 shows images of all LPH screening assessments used in this study. Prior to the data capture, the tester (KW) completed a reliability study. Eight professional rugby union players were assessed on their dominant leg for hand held dynamometry in long lever abduction and adduction, and bilateral adduction using an aneroid sphygmomanometer as per the protocols detailed below. Each participant repeated test protocol on 3 occasions, at the start of the training day on three separate days. All tests reported an intra-class correlation of greater than 0.95. The intra-tester reliability was therefore considered excellent for this study (Portney & Watkins, 2000).

Table 3.2 Intra-class correlation (ICC) coefficients for HHD and sphygmomanometer testing

| | ICC | SEM |
|---|---|---|
| Adductor Squeeze 0º | 0.998 | ± 10 mmHg |
| Adductor Squeeze at 60º | 0.987 | ± 7 mmHg |
| Adductor Squeeze at 90º | 0.995 | ± 10 mmHg |
| HHD Hip Extension | 0.989 | ± 1.9 Kg |
| HHD Hip Adduction | 0.957 | ± 1.3Kg |
| HHD Hip Abduction | 0.993 | ± 1.6Kg |

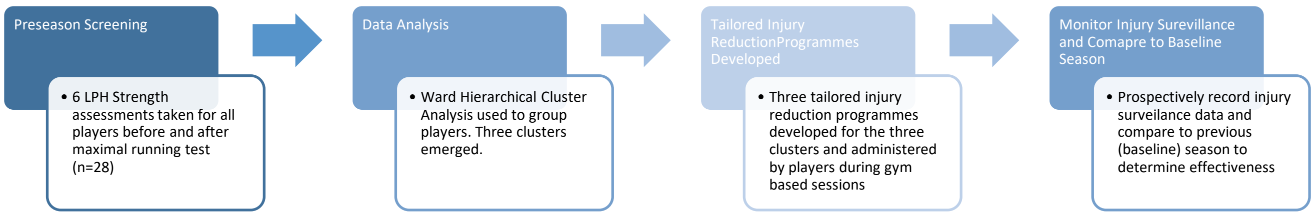



Figure 3.1 Overview of Phase 1 testing procedure completed

*Test Protocol*

Isometric adductor squeeze at 0º, 60º hip flexion and 90/90º hip and knee flexion were tested in supine using a manual sphygmomanometer (Anaeroid sphygmomanometer, Timesco, England) pre-inflated to 10mmHg and placed between the players knees such that the middle third of the cuff was located at the most prominent point of the medial femoral condyles. For 0º, the players were instructed to lie in supine with the hips and knees fully extended. The 60º position was located by bringing the medial malleolus of the right leg in line with the left tibiofemoral joint line. The left leg was then flexed up so that the medial malleoli were aligned and touching. The 90/90º position was located by positioning the patients hips and knees at 90º flexion, measured using a universal goniometer. Once positioned, the player was instructed to squeeze the cuff as hard as he could for 5 seconds. The highest-pressure reading displayed on the sphygmomanometer was recorded during each maximal adductor squeeze. Players were given 1 minute rest in between each adductor squeeze. The total time duration of testing for the squad was 60 minutes to complete from initial assessment to final assessment.

Table 3.1 Hand held dynamometry (HHD) and sphygmomanometer tests that were used to assess muscle strength of the Lumbo-Pelvic-Hip complex.

| Test | Image | Muscles indicated (Neumann, 2010) |
|---|---|---|
| Isometric adductor squeeze at 0º (ADD0) |  | Adductor magnus and gracilis |
| Isometric adductor squeeze at 60º (ADD60) |  | Adductor longus |
| Isometric adductor squeeze at 90/90º (ADD90/90) |  | Pectineus and adductor brevis |
| Side-lying hip adduction (Hip ADD) |  5cm above medial malleolus | Adductor magnus, gracilis, adductor longus, pectineus and adductor brevis |
| Side-lying hip abduction (Hip ABD) |  5cm above lateral malleolus | Gluteus medius, minimus and tensor fascia latae |
| Prone hip extension (Hip EXTN) |  | Gluteus maximus, adductor magnus, hamstrings |

Hip adduction, abduction and extension were measured on the players' dominant leg using a hand-held dynamometer (HHD) (Lafyette, USA). Once positioned, players were instructed to match the force of the tester for a period of 5-s. This ‘make’ technique is reported to have greater reliability than a ‘break’ test in dynamometry (Stratford and Balsor, 1994). Players were given two practice trials to ensure the correct action was performed and the HHD score was recorded on the third attempt. Hip extension was recorded in the short lever position with the player in prone, knee flexed to 90$^{o}$ and the HHD placed 5cm proximal to the knee joint line on the posterior thigh. Hip abduction was recorded with the player in side-lying position. The HHD was placed 5cm proximal to the lateral malleolus. Hip adduction was measured in side-lie with the HHD placed 5cm proximal to the medial malleolus. All testing was performed by a single investigator (KW).

The players’ baseline screening data was noted (ADD0 = 271± 53.4mmHg; ADD60 = 256 ±41.2;mmHg ADD 90/90 = 226 ±45.6mmHg; Hip Extn = 42.4 ±7.4Kg; Hip ADD = 42.2 ± 6.7Kg; Hip ABD 29.4 ± 5.0Kg).

Table 3.3 Phase 1 baseline data for all screening assessments

| | **Total median (min to max)** | Cluster 1 Median (min to max) | Cluster 2 median (min to max) | Cluster 3 median (min to max) |
|---|---|---|---|---|
| Abduction (kg) | **28.7 (21.3 to 43.7)** | 27.65 (25.5 to 42.6) | 29.6 (21.3 to 43.7) | 27.4 (23.9 to 32.7) |
| Adduction (kg) | **41.8 (30.7 to 56.2)** | 33.35 (30.7 to 36.6) | 42.9 (32.3 to 54.7) | 44.5 (35.4 to 56.2) |
| Hip Extension (kg) | **44.95 (21.7 to 52.4)** | 36.2 (30.2 to 36.9) | 46.1 (31.4 to 52.4) | 44.8 21.7 to 47.8) |
| Adductor Squeeze 0 (mmHg) | **285 (140 to 380)** | 190 (140 to 260) | 290 (190 to 380) | 260 (230 to 340) |
| Adductor Squeeze 60 (mmHg) | **262 (160 to 330)** | 220 (160 to 290) | 270 (170 to 330) | 264 (230 to 280) |
| Adductor Squeeze 90 (mmHg) | **220 (140 to 330)** | 220 (140 to 260) | 230 (160 to 330) | 218 (170 to 230) |

Following the baseline screening, players were then required to complete a Yo-Yo intermittent recovery test level 1 [Yo-Yo IR-1 (Bangsbo, Iaia and Krustrup, 2008)] until voluntary exhaustion. The Yo-Yo IR1 testing was administered using the standard protocol outlined by Bangsbo et al (2018) by the strength and conditioning staff on two occasions with players grouped according to position (forwards and backs). Immediately (within 90 seconds) after each player had finished the Yo-Yo IR-1 test, the screening assessments were repeated for all players to provide the post measures. The change from pre- to post- was then determined.

Players were grouped using hierarchical cluster analysis of the dominant leg pre to post change scores. Three groups emerged from Ward's hierarchical cluster analysis. A one-way between groups analysis of variance was conducted to explore the impact of cluster in changes to hip and groin strength scores. There was a statistically significant difference at the $P<0.05$ level for Adductor squeeze at $0^{o}$ (*F*= 26.901, *P* = 0.000); Adductor squeeze at $60^{o}$ (*F*= 37.970, *P* = 0.000); Adductor squeeze at $90^{o}$ (*F*= 13.879, *P* = 0.000); hip adduction (*F*= 14.615, *P* = 0.000) and hip abduction (*F*= 3.850, *P* = 0.034). Post hoc comparisons using Tukey's test was conducted. Post hoc analysis indicates that the mean score of adduction squeeze at $0^{o}$ was significantly different between cluster 1 (*M* = 67.15, *SD* = 27.53) and cluster 2 (*M* = -4.08, *SD* = 15.28) and cluster 3 (*M* = -9.69, *SD* = 21.78). Post hoc analysis for adductor squeeze at $60^{o}$ revealed significant differences between cluster 1 (*M* = 35.28, *SD* = 13.53) and cluster 2 (*M* = -5.88, *SD* = 10.92), cluster 1 and cluster 3 (*M* = -21.57, *SD* = 3.72) and cluster 2 and 3. Post hoc analysis for adductor squeeze at $90^{o}$ revealed significant differences between cluster 1 (*M* = 45.68, *SD* = 28.35) and cluster 2 (*M* = -7.74, *SD* = 18.12) and cluster 1 and cluster 3 (*M* = -10.46, *SD* =

15.18). Post hoc analysis of hip adduction changes indicates a significant difference between cluster 1 (*M* = 1.25, *SD* = 16.33) and cluster 3 (*M* = -29.65, *SD* = 5.45), and cluster 3 and cluster 2 (*M* = -7.47, *SD* = 9.58). Finally, post hoc analysis of hip abduction changes indicate a significant difference between cluster 2 (*M*= -0.24, *SD* = 14.87) and cluster 3 (*M* = 18.45, *SD* = 15.89). The significant differences are highlighted with a red asterisk in figure 3.2.

Figure 3.2 shows the distributions of the change in scores of each screening test from baseline following the YoYo IR-1 test for each cluster. These observations characterised the groups and prehabilitation priorities were identified (exercise themes) and tailored to address the likely associated issues (Table 3.4).

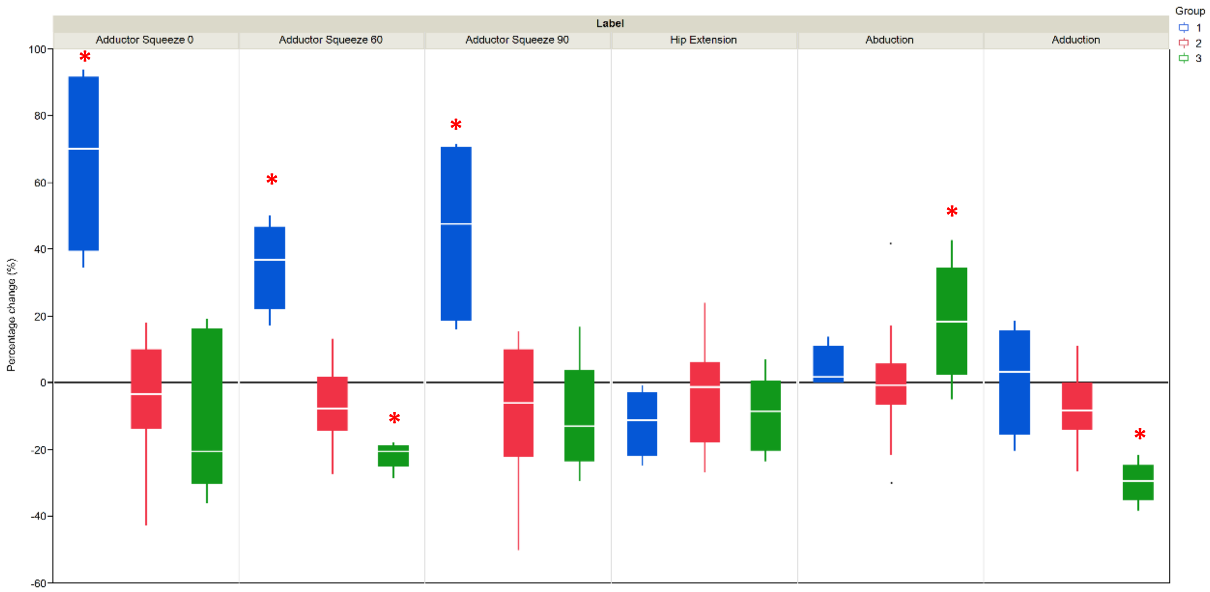



Figure 3.2 Phase 1 distributions of the change in scores from baseline following the YoYo IR-1 test by cluster (group). Cluster 1 is shown in blue, cluster 2 in red and cluster 3 in green.

Cluster 1 (N = 4, all backs, Stature = 181.8 ± 6.7 cm and Mass = 94± 8.7 kg, one player with previous medical history of LPH injury in previous 12months); showed increases in hip adductor squeezes in all three positions, and a reduction in hip extension strength post Yo-Yo IR-1.

Cluster 2 (N = 18, six backs and 12 forwards, Stature = 185.3 ± 6.7 cm and Mass = 105.5 ± 12.7kg; six players with previous medical history of LPH injury in previous 12months) showed similar responses across all hip and groin tests post Yo-Yo IR-1.

Cluster 3 (N = 6, one back and five forwards, Stature = 191.5 ± 6.9 cm and Mass = 110.6 ± 14.1 kg, no previous medical history of LPH injury in the past 12months) showed reductions in 60º adductor squeeze, hip extension strength and hip adduction strength. Cluster 3 also demonstrated an increase in hip abduction strength post Yo-Yo IR-1.

The remaining 22 players not tested (Stature = 185.2 ± 5.2 cm and Mass = 102.7 ± 10.8 kg) were composed of 10 backs and 12 forwards and one player with previous medical history of LPH injury in previous 12months.

The prehabilitation was delivered as auxiliary exercises in the player's lower limb strength and conditioning sessions throughout the rugby season (a total of 2 sessions per week for 47 weeks, mean 1.8 ± 0.4). Absence to the lower limb sessions was recorded daily and a compliance of >90% was noted for players attending sessions and completing the injury reduction exercises as prescribed. Reasons for non-compliance included illness, injury, and absence due to medical appointments, international duty and players being loaned to other teams. A

Graduate Sports Therapist and the Strength and Conditioning Coaches supervised each session. The supervision ensured that each player executed the exercises with the heaviest load possible to maintain appropriate technique as per the prevention programme.

Table 3.4 Phase 1 characteristics and prehabilitation priorities for each cluster

| Cluster | Characteristic | Exercise theme 1 | Exercise theme 2 |
|---|---|---|---|
| One | Weakness of hip extension under fatigue | Low threshold deep hip rotator Cuff | High threshold gluteus maximum loading |
| Two | Generic weakness under fatigue | Lower abdominal control | Adductor strengthening |
| Three | Weakness of adductors, hip extensors and increases in hip abduction strength under fatigue | Inner range hip flexor strength | Lower abdominal control |
| Non-clustered | N/A | Generic adductor strength | Generic abductor strength |

Table 3.5 Phase 1 example of prehabilitation exercise menu by cluster

| Cluster | Auxillary Group 1 | Auxillary Group 2 |
|---|---|---|
| One | Low threshold deep hip rotator cuff<br>- Clams x 30 reps<br>- Iso clam holds x 20sec<br>- Clam tap behinds x 30 reps<br>- Long lever beats x 30 reps<br>- Long lever circles at 90o Hip Flexion x 20r eps<br>- Quadruped IR x 30 reps<br>- Quadruped ER x 30 reps | High threshold glute max loading<br>- Prone triple extension kick backs x 12 reps<br>- Theraband 'X' walks x 8 steps<br>- Death March (with forward lean) x 8 steps<br>- SL Glute/Ham bridge x 12 reps<br>- Mini Band squats x 12 reps<br>- Mini Band crab walks x 12 steps |
| Two | Lower Abdominal Control<br>- V–sit 60º iso hold x 20sec<br>- V-sit 60º reactive abs punches x 20sec<br>- Overhead medball slams x 20sec<br>- DL 45º Reaches x 8<br>- SB jack knifes x 12<br>- Scissor Beats x 30<br>- Side Plank x up to 60sec | Adductor Strength<br>- SB sumo squats x 25<br>- Short/Long lever adductor bridges x 20sec<br>- Kneeling box step ups x 8 EL<br>- Proprio walking lunges x 12<br>- Adductor medball squeezes at 0/60/90º x 15sec<br>- SL Squat theraband sliders x 8 EL |
| Three | Inner Range Hip Flexor<br>- Kneeling Box Step Ups x 8 EL<br>- Proprio Walking Lunges x 12<br>- Rolling Spiders x 15m<br>- Kick Overs x 8 EL<br>- Mountain Climbers x 8<br>- SL Hang Clean to Wall x 8 EL | Lower Abdominal Control<br>- V–sit 60º iso hold x 20sec<br>- V-sit 60º reactive abs punches x 20sec<br>- Overhead medball slams x 20sec<br>- DL 45º Reaches x 8<br>- SB jack knifes x 12<br>- Scissor Beats x 30<br>- Side Plank x up to 60sec |
| Non-clustered | Generic Adductor Strength<br>- SB sumo squats x 25<br>- Short/Long lever adductor bridges x 20sec<br>- Kneeling box step ups x 8 EL<br>- Proprio walking lunges x 12<br>- Adductor medball squeezes at 0/60/90º x 15sec<br>- SL Squat theraband sliders x 8 EL | Generic Abductor Strength<br>- Clams x 30 reps<br>- Iso clam holds x 20sec<br>- Clam tap behinds x 30 reps<br>- Long lever beats x 30 reps<br>- Long lever circles at 90o Hip Flexion x 20r eps<br>- Quadruped IR x 30 reps<br>- Quadruped ER x 30 reps |

The effect of the preventative program was determined by a comparison of injury surveillance data between the previous baseline season and intervention season. All soft tissue injuries to the buttock/pelvis, groin, thigh and lumbar spine (identified by their OSICS code, version 10.1, Rae & Orchard, 2007) sustained via a non-contact mechanism were identified from prospective injury surveillance data, as per Rugby Injury Group Consensus (Fuller et al, 2007). Training and match injury incidence (per 1000 hours), injury prevalence (% of players unavailable) and average days-lost per injury were compared for all non-contact LPH injuries sustained over the two seasons. Injury was defined as 'a physical complaint that was sustained by a player during a rugby match or training, irrespective of the need for medical attention or time-loss from rugby activities' (Fuller et al, 2007). Injury severity is defined as the time, in days, lost from match and practice, specifically the number of days that have elapsed from the date of the injury to the date of the player's return to full participation in team training and availability for match selection (Fuller et al, 2007). Total severity and average severity was also reported. Injury incidence is generally reported relative to exposure. Using Williams et al, (2015) definition, this study reports incidence as the number of injuries per 1000 hours of rugby participation (match and training). Prevalence was also recorded. This is expressed as a percentage of the squad fit and available for selection across the season. All injury surveillance data was recorded prospectively by the researcher using a standardised electronic data collection sheet that complies with the participation agreement held between the regional team and the WRU. Exposure data was also collected using the same system and all injury surveillance data was independently verified by the national governing body.

Compliance was also recorded. Compliance was defined as the percentage of available injury reduction sessions attended and completed as per programme by players across the season. Reasons for players missing injury reduction sessions or being unable to complete injury reduction sessions as per programme include absence due to international duty, loan to another team, medical appointments or absence or incomplete sessions due to illness or injury. For example, a player diagnosed with a suspected concussion will attend the training session but strict graded return to play criteria means that they can only complete a 20 minute cycle during that first session back, even if they feel fit and well enough to complete lower limb strength training.

### 3.2.4 Data Analysis

Ward's Hierarchical cluster analysis was used to group players on the change (pre to post YoYo IR-1 test) for all hip and groin measures on the players' dominant leg. Consensus injury surveillance methods were used for data analysis. A comparison was made between seasons for LPH injury incidence, severity, average number of days lost per injury and prevalence.

## 3.3 Phase 2: End of Season Review- Players Perspectives of Injury Reduction Programmes

Following the action research cycle/ completed sequence of prevention in phase one of this study, phase 2 will consider the players perspectives of injury reduction programmes and ask them to reflect on both their experiences and preferences so as to better inform phase 3 of this study.

### 3.3.1 Method

Phase 2 of the study employed a qualitative research design. Of the fifty professional rugby union players recruited for the injury reduction programme in Intervention Season 1 (Phase 1), twenty nine contracted players completed an end of season questionnaire on their perceptions of injury prevention programmes in the last week of intervention season 1 [mean age 24.3 ± 3.5yrs, median = 24yrs (min=20, max=34); mean years in professional rugby union = 5.4 ± 3.2yrs, median = 4yrs (min=1, max=14); mean caps senior international rugby union = 2.2 ± 6.3, median = 0 (min=0, max=27)]. The remaining twenty two players were excluded by absence either due to international duty (Senior and Under 20s), retirement or termination of contract as players transferred to other professional teams. All players provided written consent for the project which was approved by the UWTSD Ethics Committee. All players had undergone a tailored injury prevention programme targeting the lumbo-pelvic-hip region in the past season which was embedded in their strength and conditioning programmes. All players had complied with the injury prevention programme (Evans, Hughes and Williams, 2018). The questionnaire was customised for the purpose of this study and administered electronically as part of a wider end of season review using a data sharing platform specifically designed for team performance management (appendix 2). The questionnaire used a combination of twenty two Likert scale answer questions and two open ended questions. Data was analysed using thematic analysis (Braun, Clarke and Weate, 2016). The electronic responses to the open ended questions were exported to excel, and units of meaning (via quotations) were identified and coded. Emergent themes were then identified using an indicative content analysis approach. Indicative content analysis, as recommended by Patton (1980), has successfully been adapted to sport by Scanlan, Gould and colleagues (Scanlan et al, 1989; Scanlan et al, 1991; Gould et al, 1993; Hanton and Jones, 1999) and was adopted in this study. Content analysis is a procedure that allows the investigator to organise raw data in to interpretable and meaningful themes and categories and allows these to emerge from the quotations. Specifically the process begins with clustering quotes around common threads, which become emergent themes (Hanton and Jones, 1999). The analysis continues to develop until further common threads cannot be located to create a higher level theme. The specific procedure adopted in this study was as follows:

1. Questionnaires were electronically reported and responses exported to excel.
2. Questionnaire responses were read and reread by the researcher to ensure familiarity with the content
3. Raw data themes (i.e. quotes and paraphrased quotes) from the responses were reread to ensure that all quotations made intuitive sense
4. Raw data themes were then compiled in list form, combining the responses of all participants
5. Indicative content analysis was then conducted to identify common themes from the list of sub-sectioned raw data. Second level themes were labelled as *'higher order themes'* and the highest level themes were labelled *'general dimensions'*
6. A deductive analysis was conducted to provide a validity check, verifying that all themes and dimensions were presented in the players responses
7. The numbers of citations in each dimension were calculated for frequency analysis

8. The researchers’ individual biases were controlled using a consensus validation procedure which involved independent analysis at each stage by the author and a second therapist not involved with the study, before discussing and progressing to the next level.

Twenty five of the twenty nine players asked reported a time loss injury during intervention season 1, with 22 players forced to miss competitive matches as a result. Injury surveillance data shows these participants had a severity of 3541 days lost, with a total of 78 injuries. 24% of injuries were sustained to the foot and ankle, 15% to the lumbo-pelvic-hip-region, 13% to both the spine and knee regions, 11% to the shoulder, 6% were head injuries and finally both the wrist and hand and elbow accounted for 5% of the total injuries sustained by this group. The remaining 8% of injuries included medical illness and lacerations. Figure 3.3 shows the self-reported severity of injuries sustained by those who participated in the study.

Table 3.6 Phase 2 Injury Incidence by anatomical region expressed as a percentage of total injuries sustained by participants

| Injury by Region | Percentage incidence |
|---|---|
| Foot and Ankle | 24% |
| Lumbo-pelvic-hip | 15% |
| Knee | 13% |
| Spine | 13% |
| Shoulder | 11% |
| Head (including concussions) | 6% |
| Elbow | 5% |
| Wrist and Hand | 5% |
| Other/Medical | 8% |

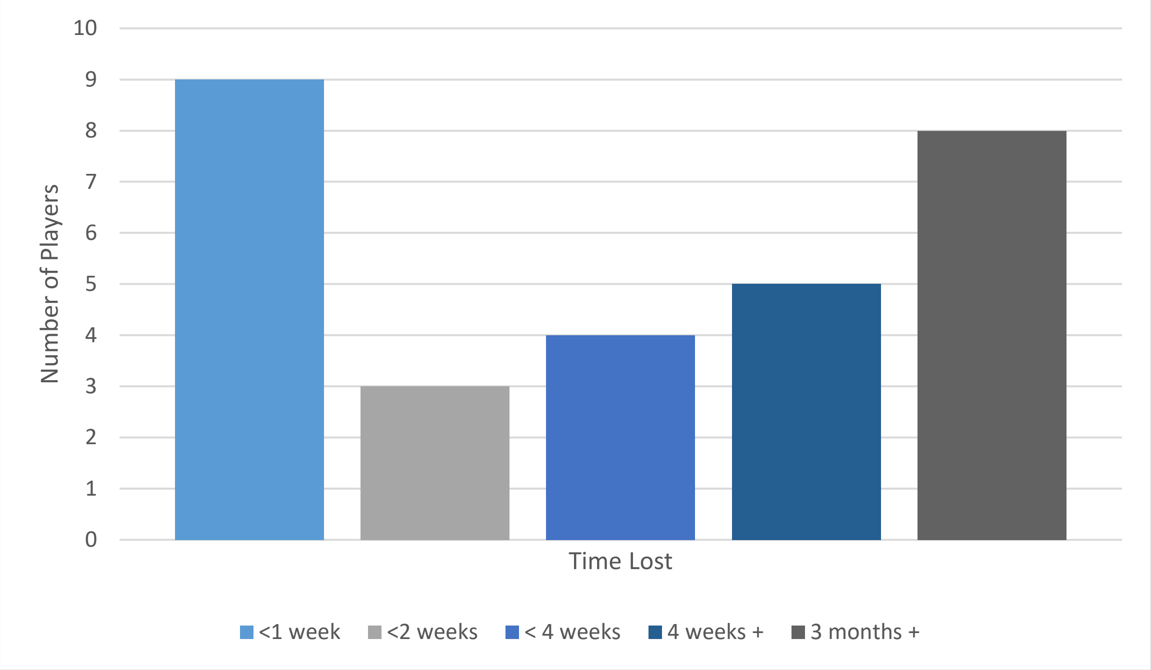



Figure 3.3 Phase 2 self-reported injury severity (time lost) by player

## 3.4 Phase 3: Second Injury Reduction Season

This final phase of the study will complete another action research cycle/ sequence of prevention. Following reflections of the first phase of the study, and the players' perceptions and preferences noted in phase 2, a number of modifications will be made to the test battery and intervention implementation.

The test battery has been expanded to include hamstring strength in both inner and outer (30$^{o}$) range of knee flexion, hip flexor strength and hip internal rotation and flexion range of movement. The addition of hamstring strength as a knee flexor has come in response to hip extension reductions in both cluster 1 and 3 of phase 1. Hamstrings assist in hip extension and it would be interesting to note any distal changes that occur to this bi-articular muscle group. As mentioned previously, the adductors are a triplaner muscle group and are considered important flexors and extensors of the hip. The addition of hip flexor strength will consider the third element of adductor function. No study has considered the role of hip flexion ROM on the aetiology of LPH injuries. However, if hip flexion ROM is reduced, it is plausible to suggest that gait may be altered, especially at higher running speeds with the potential for compensatory movement patterns to change the loading of muscles around the hip and groin. As mentioned earlier, active ROM of hip flexion is performed by iliopsoas. Iliopsoas and the lower abdominals have a synergistic relationship with the lower abdominals creating a potent posterior pelvic tilt sufficient enough to neutralise the strong anterior pelvic tilt of the hip flexor muscles (Neumann, 2010a). If the iliopsoas is insufficiently strong enough to produce inner range hip flexion active range of movement, then concerns would be raised over its ability to work synergistically with the lower abdominals.  Finally limited evidence was found from the systematic literature review for hip rotation range of motions association with sports related groin pain. Only one study (Verrall et al, 2005) considered the role of hip internal rotation on groin pain. A small number of studies have concluded that reduced total hip rotation ROM may be considered an aetiological factor in the occurrence of adductor strain and sports related groin pain. Hip flexion and rotation ROM using goniometric assessment is a quick and easy to administer test and requires equipment that is readily available in the clinical setting.

In response to the players' feedback given anonymously in phase 2 of this study, players were taken through a short educational session prior to the implementation of intervention 2. The session highlighted the injury reduction programme aims for the forthcoming season and explain clearly to players how the programme would be tailored to their individual screening results and how the sessions would be implemented. It acknowledged the players preferences and explain how and where these were be addressed.

### 3.4.1 Participants

Forty male professional regional rugby union players (age 23.8 ± 4.1 years; stature 182.4 ± 5.7 cm; mass 106 ± 14.9 kg) fit and available at the start of the third preseason volunteered to take part in this study (backs n= 16, forwards n=24. Six players had suffered a time-loss LPH injury in the previous 12 months however all players were currently asymptomatic of LPH pain and in full training. The remainder of the squad (n=12) were excluded by absence at the start of preseason (e.g. international rugby duties at Senior and Under 20s level) or injuries that were unsuitable for testing. Of the original twenty eight players, twenty two were re-screened and re-allocated to a cluster in this second season injury reduction programme. All players gave written informed consent to participate in the study, which had been approved by the University of Wales, Trinity Saint David Research Ethics Committee.

### 3.4.2 Research Design

A prospective case controlled design was used for phase 3 of this study.

### 3.4.3 Protocol

In the second intervention season the team completed 34 competitive matches per season in the domestic league and European cup competitions. In comparison the team played 35 games in the first intervention season and 34 games across three competitions in the baseline season. Finally the team played 35 competitive matches in the withdrawal season. Match and training GPS data for the four seasons were compared (Table 3.7).

Table 3.7 Summary of team training and match GPS data across four competitive rugby seasons.

| | | Baseline | | Intervention Season 1 | | Intervention Season 2 | | Withdrawal | |
|---|---|---|---|---|---|---|---|---|---|
| | | Forwards | Backs | Forwards | Backs | Forwards | Backs | Forwards | Backs |
| Training | Average distance covered per week (m) | 10738 ±1404 | 14245 ±1810 | 10768 ±1062 | 13946 ± 2032 | 11140 ± 1307 | 13067 ± 2005 | 14569 ± 1514 | 15475 ± 2104 |
| | Average training metres per minute | 38.03 ±2.58 | 56.99 ±2.6 | 47.08 ±3.5 | 55.4 ±3.1 | 55.37 ± 3.19 | 59.55 ± 2.7 | 58.9 ± 4.01 | 62.1 ± 3.2 |
| Match | Average distance covered per game | 5926 ±471 | 6470.8 ±603 | 4541 ±572 | 6957 ±641 | 3934 ± 641 | 5039 ± 687 | 4030.7 ± 648 | 5017.7 ± 645 |
| | Average Metres per minute | 66.6 ±4.61 | 80.3 ±5.02 | 68.1 ±3.1 | 78.12 ±3.9 | 71.3 ± 4.9 | 76.8 ± 4.2 | 69.8 ± 5.1 | 76.1 ± 4.6 |

A one-way between-groups analysis of variance was conducted to explore the impact of time/season on GPS metrics for forwards and backs. There was no statistically significant difference for the average distance covered for forwards during training over the three seasons (*F* = 0.516, *P* = 0.601). No statistically significant difference was found between backs training average distance across the three seasons (*F* = 1.625, *P* = 0.212). No statistically significant difference was found for backs match metres per minute across the three seasons (*F* = 2.664, *P* = 0.085).

A significant difference was found between the forwards training metres per minute over the three seasons (*F* = 128.023, *P* = 0.000). Tukey's post hoc comparisons indicates that the mean score of forwards training metres per minute for baseline (*M* = 38.03, *SD* = 2.58) was significantly different from intervention season 1 (*M* = 47.08, *SD* = 3.5) and intervention season 2 (*M* = 55.37, *SD* = 3.19).

A significant difference was found between backs training metres per minute over the three seasons (*F* = 9.172, *P* = 0.001). Tukey's post hoc comparisons indicates that the mean score of backs training metres per minute for baseline (*M* = 56.99, *SD* = 2.6) was significantly different from intervention season 2 (*M* = 59.55, *SD* = 2.7). Intervention season 2 was also significantly different from intervention season 1 (*M* = 55.4, *SD* = 3.1).

There was a statistically significant difference at the $P < 0.05$ level (*F* = 53.757, *P* =0.000) for forwards match average distance covered (m). Tukey's post hoc comparison indicates that the forwards match average distance covered in the baseline season (*M* = 5926, *SD* = 471) was significantly different from intervention season 1 (*M* = 4541, *SD* = 572) and intervention season 2 (*M* = 3934, *SD* =641).

Intervention season 1 was also found to be significantly different from intervention season 2.

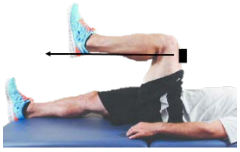
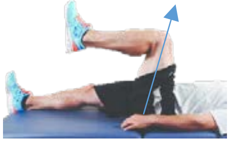
A significant difference was found between forwards match metres per minute ($F$ = 5.199, $P$ = 0.011). Tukey's post hoc comparison indicates that the forwards match metres per minute was significantly different between the baseline season ($M$ = 66.6, $SD$ = 4.61) and intervention season 2 ($M$ = 71.3, $SD$ = 4.9).

There was a statistically significant difference at the $P<0.05$ level ($F$ = 39.484, $P$ = 0.000) when comparing backs match average distance covered. Post hoc analysis using Tukey's test indicates a significant difference between baseline season ($M$ = 6470.8, $SD$ = 603) and baseline season 2 ($M$ = 5039, $SD$ = 687), and between intervention season 1 ($M$ = 6957, $SD$ = 641) and intervention season 2.

Table 3.8 shows the LPH screening assessments used in this study. The reliability of the tester (KW) has been reported earlier (Phase 1) and in the subsequent paper (Evans, Hughes and Williams, 2018). Additional protocols were included in this study, however all assessments were highly reliable. Intraclass correlation coefficients (ICC) for this specific tester range from 0.95 to 0.99 in handheld dynamometry and sphygmomanometer assessment of the hip and groin. This is better than the typical error published within the literature. Ieiri et al (2015) reported an ICC of 0.89- 0.95 for hip adduction, and Thorborg et al (2010) reported a 3-12% measurement variation in six hip strength tests.

Table 3.8 Hand held dynamometry (HHD), sphygmomanometer and goniometer tests that were used to assess muscle strength of the Lumbo-Pelvic-Hip complex.

| Test | Image | Muscles indicated (Neumann, 2010) |
|---|---|---|
| Isometric adductor squeeze at 0º (ADD0) |  | Adductor magnus and gracilis |
| Isometric adductor squeeze at 60º (ADD60) |  | Adductor longus |
| Isometric adductor squeeze at 90/90º (ADD90/90) |  | Pectineus and adductor brevis |
| Side-lying hip adduction strength (Hip ADD) |  5cm above medial malleolus | Adductor magnus, gracilis, adductor longus, pectineus and adductor brevis |
| Side-lying hip abduction strength (Hip ABD) |  5cm above lateral malleolus | Gluteus medius, minimus and tensor fascia latae |
| Prone hip extension strength (Hip EXTN) |  | Gluteus maximus, adductor magnus, hamstrings |
| Hamstring Inner Strength (HS Inner) |  | Biceps Femoris, Semi Membranosus, Semi Tendinosus |

| | | |
|---|---|---|
| Hamstring strength at $30^{o}$ flexion (HS 30) |  | Biceps Femoris, Semi Membranosus, Semi Tendinosus |
| Hip Flexor Strength (Hip FLXN) |  | Iliopsoas |
| Hip Flexion ROM (FLXN ROM) |  | NA |
| Hip Internal Rotation ROM (IR ROM) |  | NA |

In addition to the tests reported in Phase 1, and in response to some of the limitations of the earlier study additional tests were added to the protocol. Hamstring strength was measured using hand held dynamometery. The patient was positioned in prone and the HHD was placed on the posterior aspect of the tibial shaft below the gastrocnemius muscles approximately 5cm about the Achilles Tendon calcaneal insertion. Participants were asked to complete an isometric break test in $30^{o}$ of knee flexion and in hamstring inner range, where the ankle was brought as close to the gluteals as actively possible. Hip flexion strength was assessed in supination with the participant in active hip flexion. The HHD was placed 5cm from the tibiofemoral joint on the distal femur. Two range of movement tests were also completed. Hip flexion active range of movement required the supine patient to bring their knee to the chest as far as they could. This range was measured using a goniometer with the axis in line with the greater trochanter, the fixed arm on the horizontal axis and the moveable arm following the shaft of the femur to the lateral epicondyle. Hip internal rotation required the supine patient to flex the hip and knee to 90°. The participant was then instructed to rotate their hip inwards thus moving the ankle away from the midline. A goniometer was used to measure range of movement with the axis directly over the knee and hip joints, the fixed arm remaining on the vertical axis and the moveable arm following the shaft of the tibia through to the second toe. The total time duration of testing for the squad of 40 players was 75 minutes to complete from initial assessment to final assessment. The players' baseline screening data was noted and reported in Table 3.9.

Table 3.9 Comparison of mean baseline data between preseasons

| | Intervention Season 1 | Intervention Season 2 |
|---|---|---|
| Abduction (Kg) | 29.4 ± 5.0 | 20.3 ± 3.4 |
| Adduction (Kg) | 42.2 ± 6.7 | 26.5 ± 5.8 |
| Hip Extension (Kg) | 42.4 ± 7.4 | 39.4 ± 4.8 |
| Adductor Squeeze 0 (mmHg) | 271 ± 53.4 | 244 ± 49.1 |
| Adductor Squeeze 60 (mmHg) | 256 ± 41.2 | 236 ± 47.2 |
| Adductor Squeeze 90 (mmHg) | 226 ± 45.6 | 202 ± 51.8 |
| Hamstring Inner Range (Kg) | NA | 32.4 ± 6.5 |
| Hamstring 30 (Kg) | NA | 35.7 ± 4.3 |
| Hip Flexor (Kg) | NA | 30.6 ± 3.7 |
| Hip Flexion ROM (°) | NA | 120.9 ± 8.8 |
| Hip Internal Rotation ROM (°) | NA | 30.7 ± 6.8 |

Following the baseline screening, players were then required to complete a Yo-Yo intermittent recovery test level 1 [Yo-Yo IR-1 (Bangsbo, Iaia and Krustrup, 2008)] until voluntary exhaustion. The Yo-Yo IR1 testing was administered by strength and conditioning staff on two occasions with players grouped according to position (forwards and backs). Immediately (within 90seconds) after each player had finished the Yo-Yo IR-1 test, the screening assessments were repeated for all players.

Injury reduction groups were then determined using Ward's hierarchical cluster analysis of the changes to the preferred (dominant) leg data post fatigue. Two clusters emerged from the cluster analysis. An independent samples T-test was conducted to compare the changes to screening test results under fatigue between the two clusters. Hamstring strength at $30^o$ differed significantly between cluster 1 (*M* = -14.74, *SD* = 8.89) and cluster 2 (*M* = -3.42, *SD* = 11.71; *t* = -3.470, *P* = 0.001). Hamstring strength in inner range was significantly different between cluster 1 (*M* = -10.39, *SD* = 14.2) and cluster 2 (*M* = 5.46, *SD* = 14.5; *t* = -3.471, *P* = 0.001). Hip flexor strength was significantly different between cluster 1 (*M* = -8.68, *SD* = 9.64) and cluster 2 (*M* = 8.45, *SD* = 13.3; *t* = -4.722, *P* = 0.000). Hip Abduction strength changes were significantly different between cluster 1 (*M* = 13.55, *SD* = 20.09) and cluster 2 (*M* = -3.99, *SD* = 17.6; *t* = 2.875, *P* = 0.001). Hip adduction strength changes were significantly different between cluster 1 (*M* = -1.73, *SD* = 16.50) and cluster 2 (*M* = 22.3, *SD* = 25.3; *t* = -3.641, *P* = 0.001). Hip internal rotation ROM was also significantly different between cluster 1 (*M* = -14.0, *SD* = 16.33) and cluster 2 (*M* = 3.18, *SD* = 25.5; *t* = -2.595, *P* = 0.01). The significant differences are highlighted on figure 3.4 using red asterisks.

Figure 3.4 shows the distributions of the change in scores of each screening test from baseline following the YoYo IR-1 test for each cluster. These observations characterised the groups and prehabilitation priorities were identified (exercise themes) and tailored to address the likely associated issues (Table 3.11)

Table 3.10 Baseline data for all screening assessments for Intervention Season 2 Preseason

| | **Total median (min to max)** | Cluster 1 Median (min to max) | Cluster 2 median (min to max) |
|---|---|---|---|
| Abduction (Kg) | **19.45 (15.2 to 32.1)** | 19.4 (15.2 to 32.1) | 19.9 (15.7 to 25.7) |
| Adduction (Kg) | **26.9 (15.8 to 37.2)** | 27.6 (17.4 to 37.2) | 24.3 (15.8 to 33.9) |
| Hip Extension (Kg) | **39.25 (26.7 to 50.6)** | 39.7 (33.7 to 49.7) | 37.8 (26.7 to 50.6) |
| Adductor Squeeze 0 (mmHg) | **255 (120 to 300)** | 250 (140 to 300) | 260 (120 to 300) |
| Adductor Squeeze 60 (mmHg) | **237.5 (150 to 300)** | 235 (150 to 300) | 240 (160 to 300) |
| Adductor Squeeze 90 (mmHg) | **200 (110 to 300)** | 185 (130 to 300) | 210 (110 to 300) |
| Hamstring Inner (Kg) | **33.45 (12 to 43.2)** | 34.1 (15.4 to 43.2) | 31.8 (12 to 40.4) |
| Hamstring 30$^{o}$ (Kg) | **35.75 (26.2 to 45.3)** | 36.6 (26.7 to 45.3) | 33.5 (26.2 to 39.7) |
| Hip Flexor (Kg) | **30.5 (26.7 to 37.4)** | 30.7 (25.1 to 37.4) | 29.9 (23.2 to 35.5) |
| Hip Flexion ROM ($^{o}$) | **121.5 (100 to 150)** | 122 (105 to 132) | 121 (100 to 150) |
| Hip Internal Rotation ROM ($^{o}$) | **30 (20 to 45)** | 30 (20 to 45) | 30 (21 to 45) |

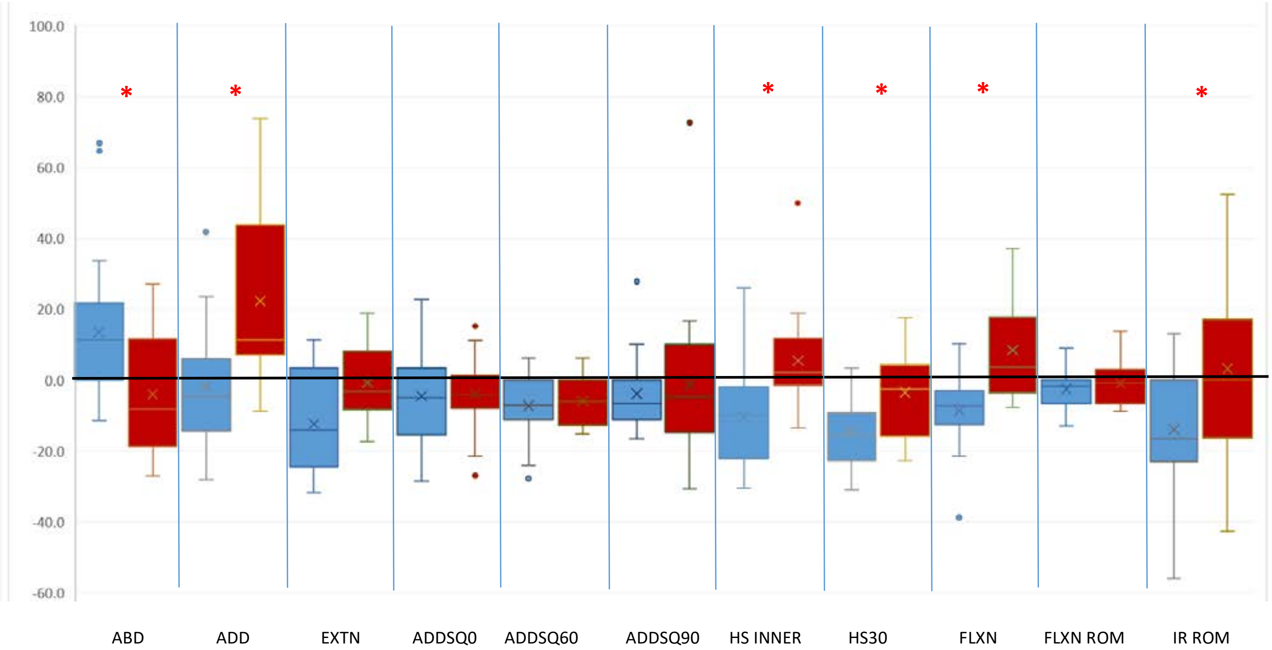



Figure 3.4 shows the distributions of the change in scores from baseline following the YoYo IR-1 test by cluster (group). Cluster 1 is shown in blue, cluster 2 in red.

Cluster 1 (N = 23; seventeen forwards, six backs. Age = 25.7 ± 3.3 yrs, Stature = 186.9 ± 6.9 cm and Mass = 108.1± 13.0 kg, three player with previous medical history of LPH injury in previous 12 months); showed increases in hip adductor squeezes in all three positions, and a reduction in hip extension strength post Yo-Yo IR-1.

Players in cluster 2 (N = 17, ten backs and seven forwards, Age = 26.8 ± 3.9 yrs, Stature = 184.7 ± 5.1 cm and Mass = 101.8 ± 9.7kg; six players with previous medical history of LPH injury in previous 12months) were characterised by decreases in hip extension, adductor, hamstring and hip flexor strength and reductions in hip range of movement with increases in hip abduction strength post Yo-Yo IR-1.

The remaining 12 players not tested (Age = 24.8 ± 4.8yrs, Stature = 185.3 ± 4.8 cm and Mass = 103.2 ± 13.5 kg) were composed of seven backs and five forwards and four players with previous medical history of LPH injury in previous 12months.

Following the screening and prior to the implementation of the second intervention, players were given a short overview of the injury prevention strategy for the forthcoming season. In this session (delivered jointly by both medical and strength and conditioning staff) the screening results were explained to players, as were the clusters and interventions attached to each cluster. Players were told that the tailored intervention would be administered within their lower limb strength and conditioning sessions. Players were given the opportunity to ask questions and discuss their screening results further with the medical department.

The prehabilitation was delivered as per the previous year, as auxiliary exercises in the players lower limb strength and conditioning sessions throughout the rugby season (a total of 2 sessions per week for 47 weeks, mean 1.8 ± 0.4, compliance >90%). A Graduate Sports Therapist and the Strength and Conditioning Coaches supervised each session. The supervision ensured that each player executed the exercises with the heaviest load possible to maintain appropriate technique as per the prevention programme.

Table 3.11 Characteristics and prehabilitation priorities for each cluster

| Cluster | Characteristic | Exercise theme 1 | Exercise theme 2 |
|---|---|---|---|
| One | Weakness of hip extension under fatigue | Low threshold deep hip rotator<br>Cuff | High threshold gluteus maximum loading |
| Two | Generic weakness under fatigue | Lower abdominal control | Adductor strengthening |
| Non-clustered | N/A | Generic adductor strength | Generic abductor strength |

Table 3.12 Example of prehabilitation exercise menu by cluster

| Cluster | Auxillary Group 1 | Auxillary Group 2 |
|---|---|---|
| One | Low threshold deep hip rotator cuff<br>- Clams x 30 reps<br>- Iso clam holds x 20sec<br>- Clam tap behinds x 30 reps<br>- Long lever beats x 30 reps<br>- Long lever circles at 90o Hip Flexion x 20r eps<br>- Quadruped IR x 30 reps<br>- Quadruped ER x 30 reps | High threshold glute max loading<br>- Prone triple extension kick backs x 12 reps<br>- Theraband 'X' walks x 8 steps<br>- Death March (with forward lean) x 8 steps<br>- SL Glute/Ham bridge x 12 reps<br>- Mini Band squats x 12 reps<br>- Mini Band crab walks x 12 steps |
| Two | Lower Abdominal Control<br>- V–sit 60º iso hold x 20sec<br>- V-sit 60º reactive abs punches x 20sec<br>- Overhead medball slams x 20sec<br>- DL 45º Reaches x 8<br>- SB jack knifes x 12<br>- Scissor Beats x 30<br>- Side Plank x up to 60sec | Adductor Strength<br>- SB sumo squats x 25<br>- Short/Long lever adductor bridges x 20sec<br>- Kneeling box step ups x 8 EL<br>- Proprio walking lunges x 12<br>- Adductor medball squeezes at 0/60/90º x 15sec<br>- SL Squat theraband sliders x 8 EL |
| Non-clustered | Generic Adductor Strength<br>- SB sumo squats x 25<br>- Short/Long lever adductor bridges x 20sec<br>- Kneeling box step ups x 8 EL<br>- Proprio walking lunges x 12<br>- Adductor medball squeezes at 0/60/90º x 15sec<br>- SL Squat theraband sliders x 8 EL | Generic Abductor Strength<br>- Clams x 30 reps<br>- Iso clam holds x 20sec<br>- Clam tap behinds x 30 reps<br>- Long lever beats x 30 reps<br>- Long lever circles at 90º Hip Flexion x 20 reps<br>- Quadruped IR x 30 reps<br>- Quadruped ER x 30 reps |

To evaluate the effectiveness of the injury reduction programme a comparison of injury surveillance data between the previous two seasons (baseline and Intervention season 1) and intervention season 2 was made. All soft tissue injuries to the buttock/pelvis, groin, thigh and lumbar spine (identified by their OSICS code, version 10.1, Rae & Orchard, 2007) sustained via a non-contact mechanism were identified from prospective injury surveillance data across the final two seasons. Training and match injury incidence (per 1000 hours), injury prevalence (% of players unavailable) and average days-lost per injury were compared for all non-contact LPH injuries sustained across the four seasons using the same definitions as used in the baseline and intervention season 1.

### 3.4.4 Data Analysis

The same data analysis method was used as described in Phase 1. In the second intervention season Ward's Hierarchical cluster analysis was used to group players on the change (pre to post YoYo IR-1 test) for all hip and groin measures on the players' dominant leg. Consensus injury surveillance methods were used for data analysis. A comparison was made across the three seasons for LPH injury incidence, severity, average number of days lost per injury and prevalence.

## 3.5 Summary of Method

Following the systematic literature review in chapter 2, a number of methodological flaws were noted in the existing literature. A mixed-method, pragmatic, insider action researcher approach was taken to ensure high levels of ecological validity. Methodological limitations of previous studies were noted and informed the current study’s research protocol. The study was split in to three phases spanning four competitive rugby union seasons. Where appropriate, rugby injury surveillance guidelines were strictly adhered too. Dominant limb measurements were taken using protocols with reported reliability coefficients. Interventions were reported in accordance with the CERT guidelines and compliance was recorded throughout. Players’ perceptions were anonymously questioned and changes to the programme were made in accordance with players’ preferences. Players were also educated on the nature of the intervention in phase 3 prior to its delivery.

# Chapter 4 Results

## 4.0 Introduction to the Chapter

The purpose of this chapter is to present the outcomes of the individual phases of this study.

An overview of the research process used within this study is represented in figure 1.12.

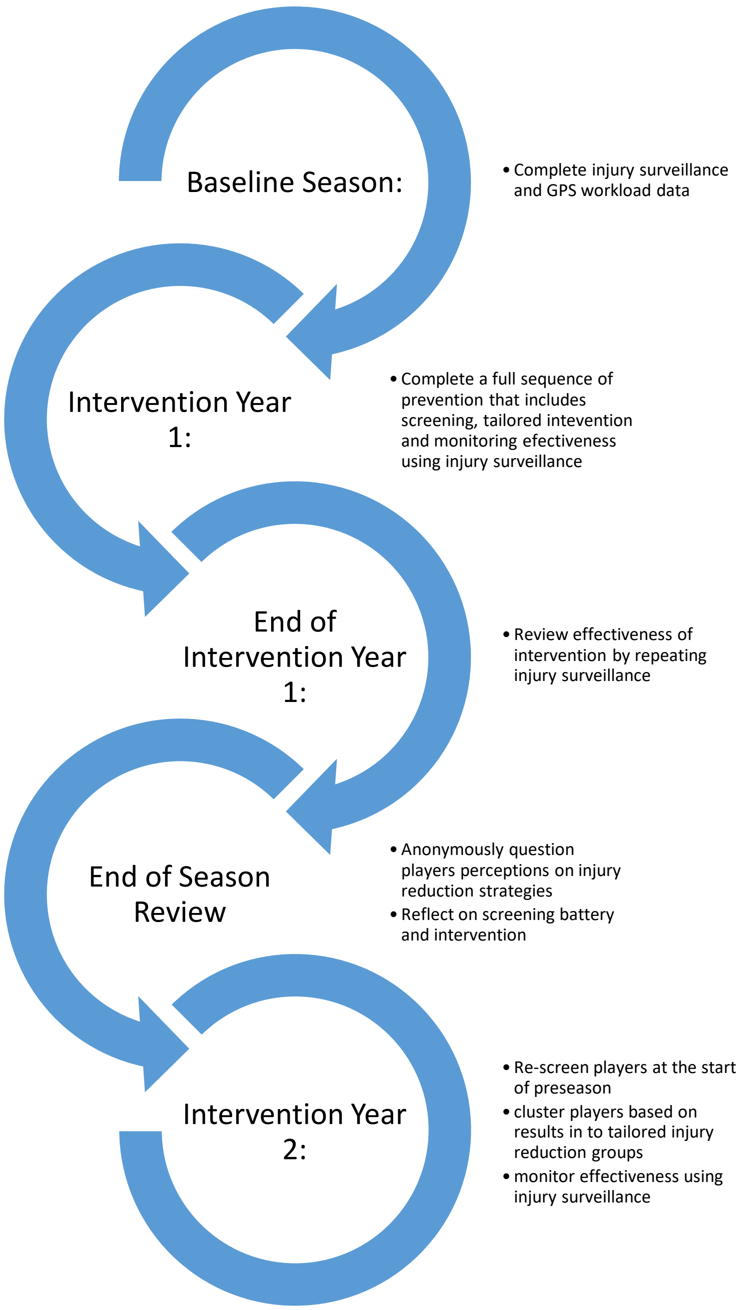



Figure 1.12 Overview of the research process.

## 4.1 Results from Phase 1: Baseline Season to Intervention Season 1

When comparing the baseline and intervention seasons: total incidence of non-contact LPH injury per 1000hours remained stable (1.5 v 1.6); total severity of LPH was halved (936d v 468d); average time to return to play was reduced by 54% (78 ±126, min 3, max 285 v 42±37, min 5, max 111); and prevalence decreased by 2% (21 v 19). Compliance was recorded at 92%.

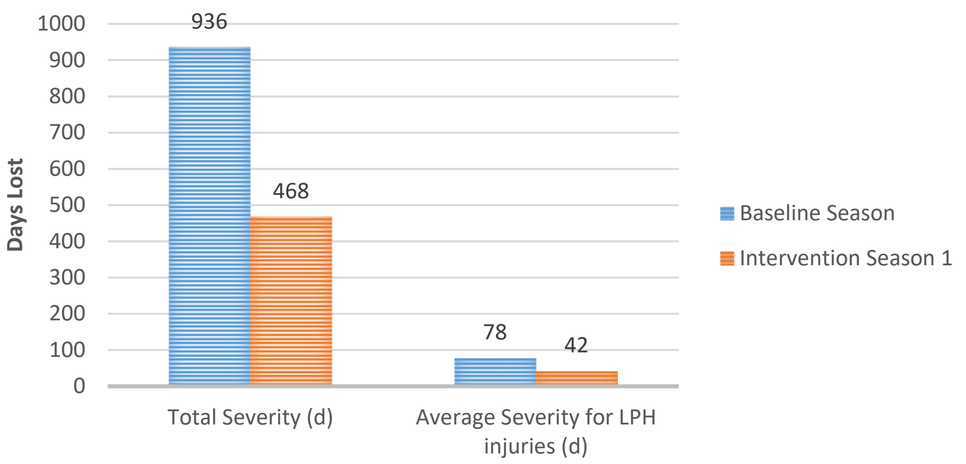



Figure 4.0 Total Severity and Average Severity of Baseline season versus Intervention Season 1

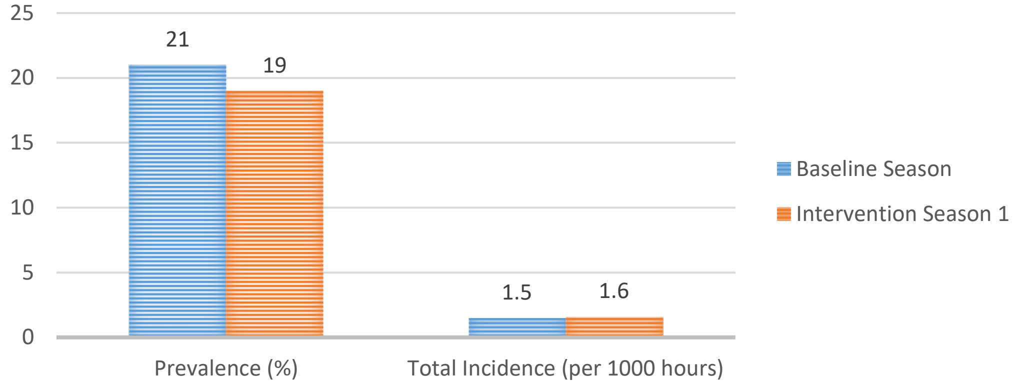



Figure 4.1 Prevalence and Total Severity of Baseline Season versus Intervention Season 1

At the group level, Cluster 1 sustained four LPH injuries resulting in a total of 65 days lost (median = 9, min = 0 max = 47d). Cluster 2 sustained four LPH injuries resulting in a total of 144 days lost (median = 16.5, min = 2, max = 109d). No player in cluster 3 sustained a time-loss LPH injury during the 2015-2016 season. Players in the control group sustained a total of 7 time-loss LPH injuries during the 2015-2016 resulting in 259 days lost (median = 21, min = 8, max = 111d).

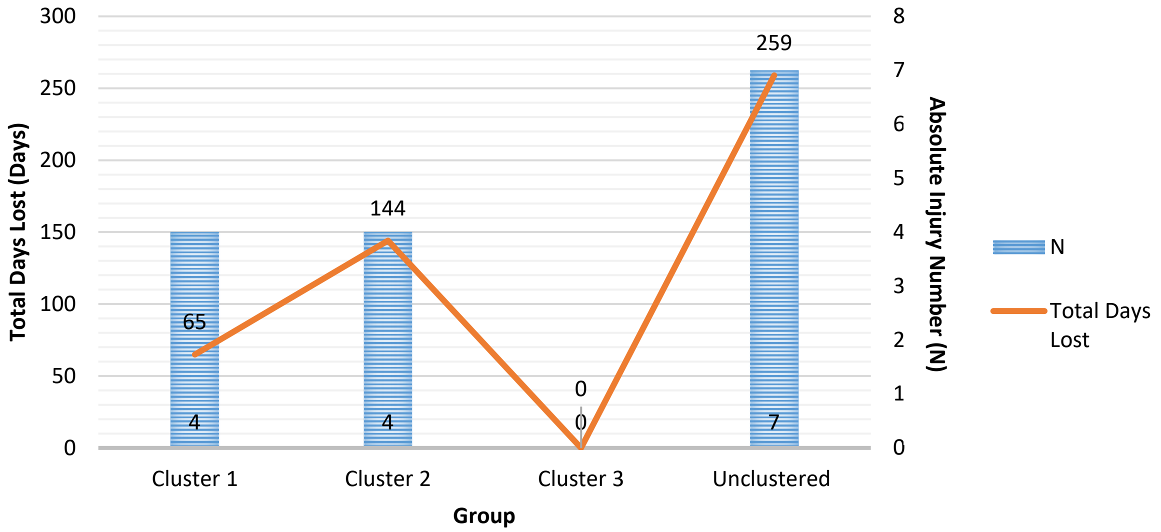



Figure 4.2 Total Injury Incidence and Injury Frequency by Group

## 4.2 Results from Phase 2: End of Season Review (Players Perspectives of Injury Reduction Programmes)

Twenty five of the twenty nine players asked had suffered a time loss injury during intervention season 1, with 22 players forced to miss competitive matches as a result. Players were asked to self-report the timeframe they were unavailable for selection due to injury in the previous season. Results are presented in Figure 3.3. Injury surveillance data shows that the respondents collectively lost 3541 days due to 78 recorded illnesses and injuries in the previous season. Injury incidence by anatomical region is recorded in table 3.6. Players were asked to identify if they had been involved in any injury prevention or prehabilitation work this previous season. Twenty five out of the twenty nine players stated they had performed injury prevention or prehabilitation work. Twenty one players stated they felt they would benefit from injury prevention education. All players had participated in a tailored injury reduction programme in the previous season, however this was implemented as part of gym based strength sessions and players were not explicitly told that it was 'injury prevention'. The questionnaire used is presented in appendix 2.

### Questionnaire Data:

For questions relating to players beliefs in the rationale for injury reduction programmes the response was mostly positive. Results from these questions are presented in Figure 4.3. Ninety seven percent of respondents agreed or strongly agreed that injury prevention or prehabilitation strategies should be used to enhance player welfare, 90% agreed or strongly agreed that such strategies should be used to improve team success, 69% agreed or strongly agreed that injury prevention strategies should be used to reduce the financial burden on the team and finally, 100% of players agreed injury prevention should be used to enhance players career longevity.

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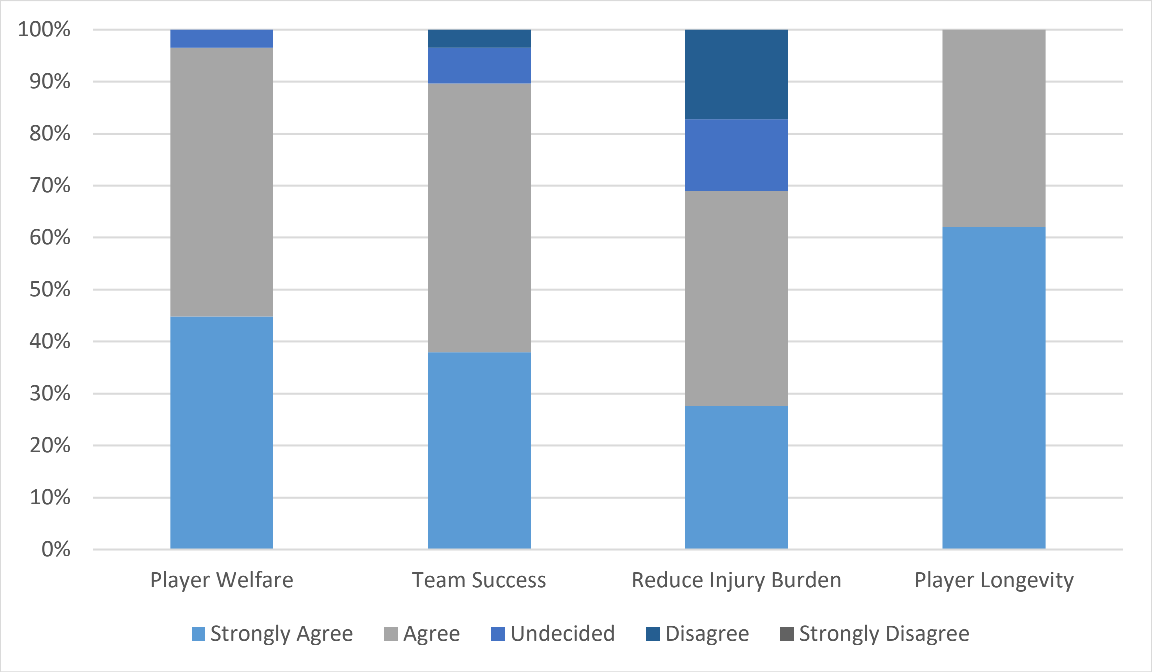


Figure 4.3 Players beliefs in the rationale for injury prevention and prehabilitation.

When asked to rate their active engagement in injury prevention in the previous season, seven players stated they strongly agree that they had been actively engaged, 13 players agreed and 9 players were undecided.

As shown in Figure 4.4, the general consensus was that no clear predominant provider of prehabilitation was apparent. Eighty three percent of respondents agreed or strongly agreed that the medical team had led on their prehabilitation, 72% positively reported a strength and conditioning lead, 80% positively reported their prehabilitation was self-directed, and 81% of players agreed or strongly agreed that their prehabilitation over the past season had been a combination of all three.

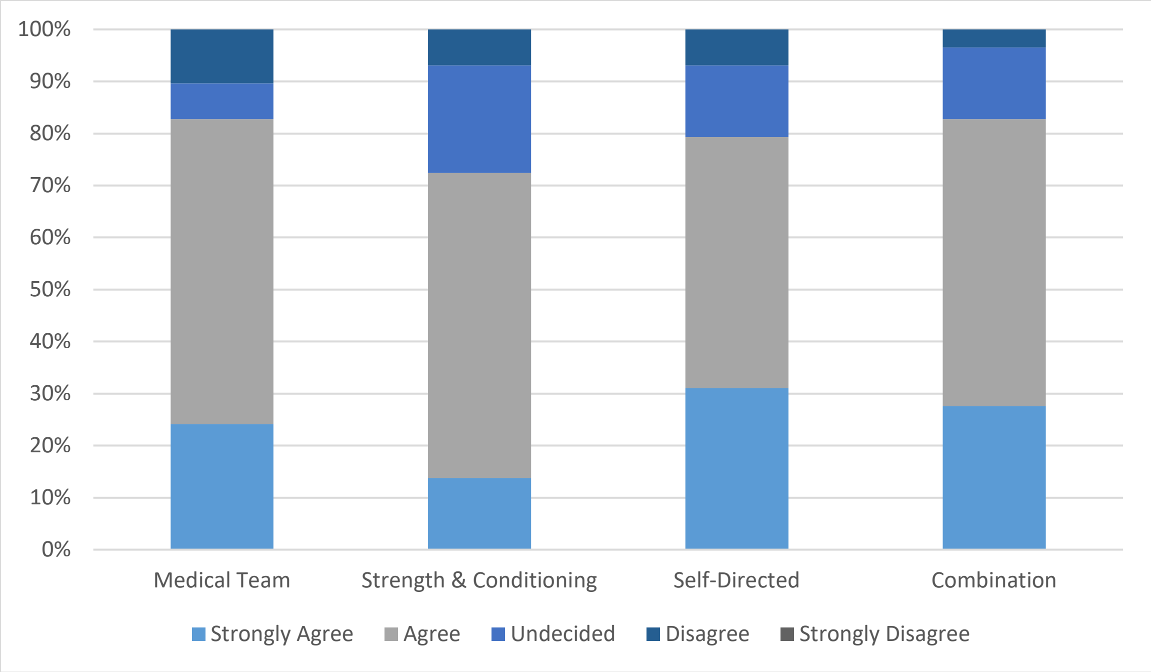


Figure 4.4 Players perceptions regarding who led their injury prevention programme over the past season.

The results for the players' perceptions on tailored injury prevention programmes are presented in figure 4.5. Overall, the responses suggest that a programme should be tailored to the player. Only one player disagreed that the programme should be consistent for those with similar injury history, with more disagreeing (n=6) that the programme should be position based. The 'same across the squad/one-size-fits-all' response, was received with the greatest resistance with 72% of respondents disagreeing or strongly disagreeing.

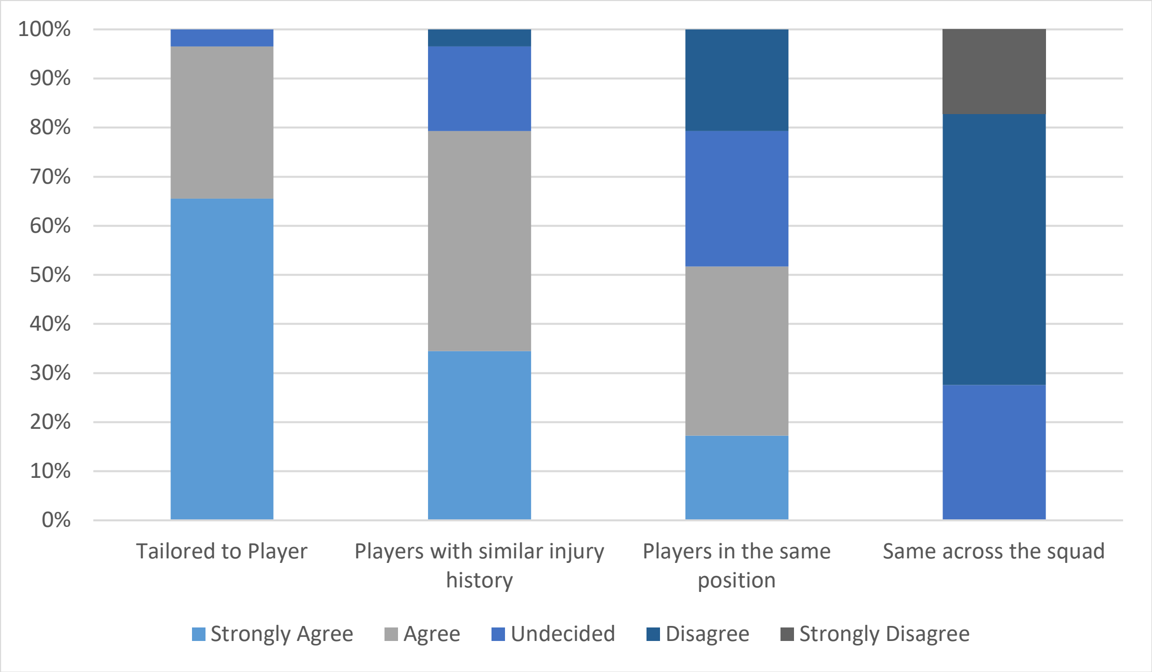


Figure 4.5 Players perceptions on tailored injury prevention programmes.

When asked about the implementation of injury prevention programmes/ prehabilitation in to their working schedule, most considered that the programme should be integrated in to strength and conditioning sessions and warm ups, less players agreed that a separate time should be allocated in their working day (Figure 4.6).

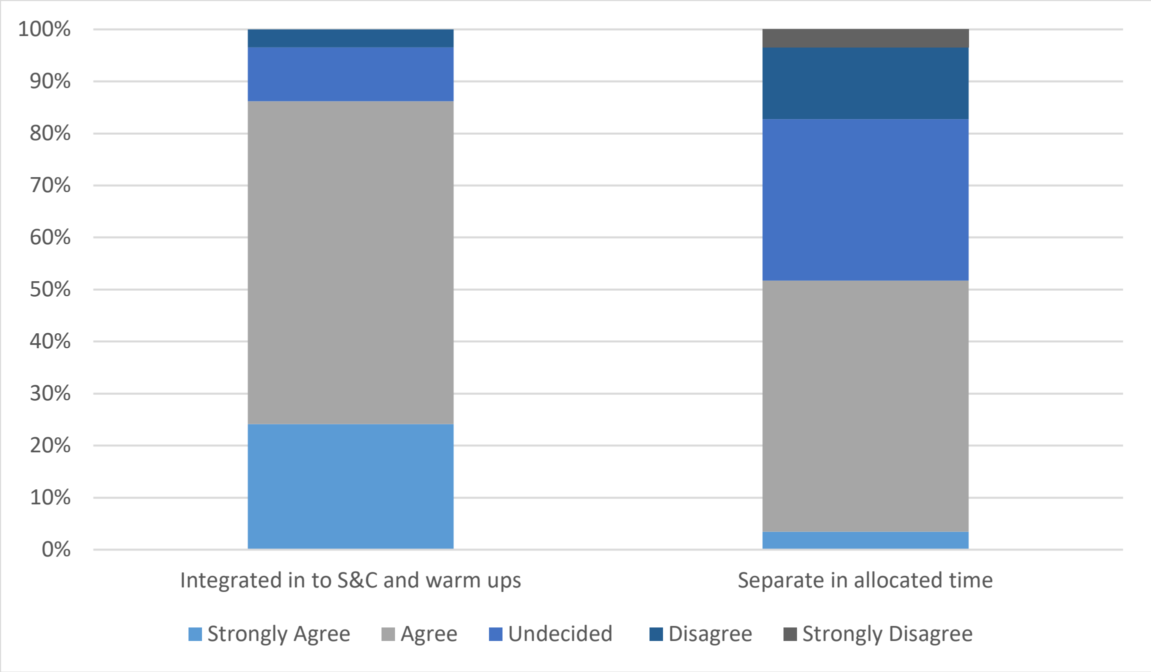


Figure 4.6 Players perceptions on placement on injury prevention programmes on schedule.

Players identified the lumbo-pelvic-hip (39%) and shoulder (30%) as important areas of injury prevention or prehabilitation for the forthcoming season. Foot and ankle and cervical spine were secondary features (Figure 4.7).

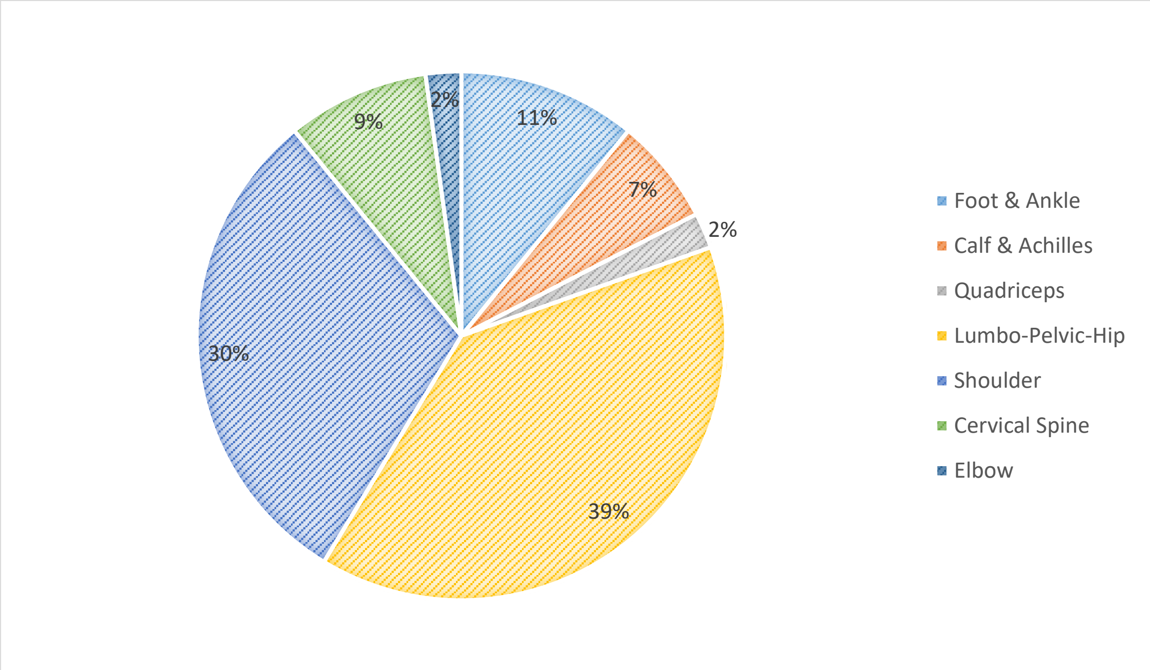


Figure 4.7 Players perceptions of their injury prevention priorities for the forthcoming season.

## Open ended questions:

General themes regarding the injury prevention programme and prehabilitation services offered by the region, with specific emphasis on how to improve the current provision are presented in figure 4.8. A thematic analysis of players' recommendations for improvements to injury prevention and prehabilitation is presented in table 4.0. Players reported three key dimensions in their injury prevention preferences. Firstly, that this is an area that is both important and expected in an elite/professional environment. Players reported that injury prevention and prehabilitation should be mandatory, preferably a separate session (not integrated in to another session) that is either performed at the beginning of the day or pre-weights sessions. Secondly players reported that injury prevention and prehabilitation should be individualised and tailored to the player themselves, specifically to their injury history and constructed in discussion with the player. The third theme to emerge was that of ‘quality’. Players reported that they want their prehabilitation sessions to be a quality interaction, with dedicated staff – preferably medical/’physio’ led or strength and conditioning led and that all sessions should be supervised.

Figure 4.8 Emerging themes from the question of improving current provision (allocated by frequency of comments).

Table 4.0 Thematic Analysis of players' recommendations for improvements to injury prevention and prehabilitation.

| **Example Quotes** | **Higher Order Theme** | **General Dimension** |
|---|---|---|
| Individual prehab/ rehab plans needed - not the same one for everyone | Tailored | Individual |
| Individual plan not same as everyone else | | |
| Don't give me the same programme as everyone else - be specific based on me | | |
| Give each player an individual prehab program to follow | | |
| I think I know what I need to work on, but it would be better if it was discussed with me | Discussed with the Player | |
| I need to know what I should do to help me and my niggles | | |
| I have lots of old injuries I need to stay on top of. | Based on previous injury | |
| I need help in putting a programme together for my history | | |
| Prehab must be separate session, not just a warm up | Separate | Important & Expected |
| Few minutes before sessions is not enough | | |
| A separate allocated session | | |
| Make us come in early and do it. There's not enough time to integrate it into our weights sessions | Not Integrated | |
| Less heavy weights without joint movement and stretches - should be something we do before heavy weights | Pre-weights | |
| Have a morning slot so we are able to complete some rehab before weights, meaning weights could start 30mins later. | | |
| 10 mins prior to gym for Prehab | | |
| In the beginning of day, sessions on planner with my own programme that I'm supervised doing | Beginning of Day | |
| Start of day before weights - ideally based on my specific needs | | |
| It's expected in professional rugby – it should be mandatory for all players, we must have quality prehab. | Mandatory | |

| Example Quotes | Higher Order Theme | Dimension |
|---|---|---|
| Ensure all Physio sessions with players are quality | Quality Interaction | Quality |
| It's not just tick box session, these must be high quality or there's no point | | |
| Must be quality prehab | | |
| Need dedicated staff, one on one to make sure I do it properly | Dedicated staff | |
| More physio led sessions based in what I need to perform at my best | Physiotherapy led | |
| More prehab involvement from physios | | |
| Too important to be left to players to do on their own – players must be supervised and there must be buy in from everyone | Supervised | |
| Give me specific exercise and supervise sessions so I know I am doing them correctly | | |

## 4.3 Results from Phase 3: Second Intervention

When comparing the intervention season 2 to the previously reported baseline and intervention season 1: total incidence of non-contact LPH injury per 1000hours remained stable in intervention season 2 (1.7/1000 hours exposure versus 1.5 in intervention season 1 and 1.6 in the baseline season); total severity of LPH was continued to reduce from 936d in the baseline season and 468d in the intervention season 1 to 417d in intervention season 2. Average time to return to play continued to reduce by 70% on intervention season 1 (12.6 ± 24, min 0, max 124 v 42±37, min 5, max 111); and prevalence decreased by 6% (13 v 19). Compliance was recorded as 91% of all sessions attended and completed as per programme.

At the group level, Cluster 1 sustained eleven LPH injuries resulting in a total of 41 days lost. Cluster 2 sustained thirteen LPH injuries resulting in a total of 99 days lost. Nine player in cluster 3 sustained a time-loss LPH injury during intervention season

2. Players in the control group sustained a total of nine time-loss LPH injuries during intervention season 2 resulting in 277 days lost.

Table 4.1 Severity of LPH Injury in intervention season 2 by group (days lost)

| Cluster | Total number of LPH Injuries | Severity of LPH Injury (days lost) |
|---|---|---|
| One | 11 | 41d (median =0, min = 0 max = 20d) |
| Two | 13 | 99d (median = 6, min = 0, max = 31d) |
| Control | 9 | 277d (median = 14, min =0, max = 124d) |

Table 4.2 A comparison of injury surveillance data for one team across four professional rugby union seasons.

| | **Baseline Season** | **Intervention Season 1** | **Intervention Season 2** |
|---|---|---|---|
| Total Incidence (per 1000 hours) | 1.5 | 1.6 | 1.7 |
| Total Severity (d) non-contact LPH injuries | 936 | 468 | 417 |
| Average Severity for LPH injuries (d) | 78 ±126<br>(min 3, max 285) | 42±37<br>(min 5, max 111) | 12.6±24<br>(min 0, max 124) |
| Prevalence (%) | 21 | 19 | 13 |

A Kruskal-Wallis H test showed a statistically significant difference in average severity for LPH injuries across the three seasons, [ $\chi^2$ (2) = 9.439, P = 0.009 ], with a mean rank score for average severity of 39.83 for baseline season, 36.40 for intervention season 1 and 24.42 for intervention season 2. Post hoc analysis was completed using a Mann Whitney U test. A significant difference was found between baseline season and intervention season 2 ($U$ = 99.5, $P$ = 0.009), and intervention season 1 and intervention season 2 ($U$ = 145.5, $P$ = 0.020) for average severity.

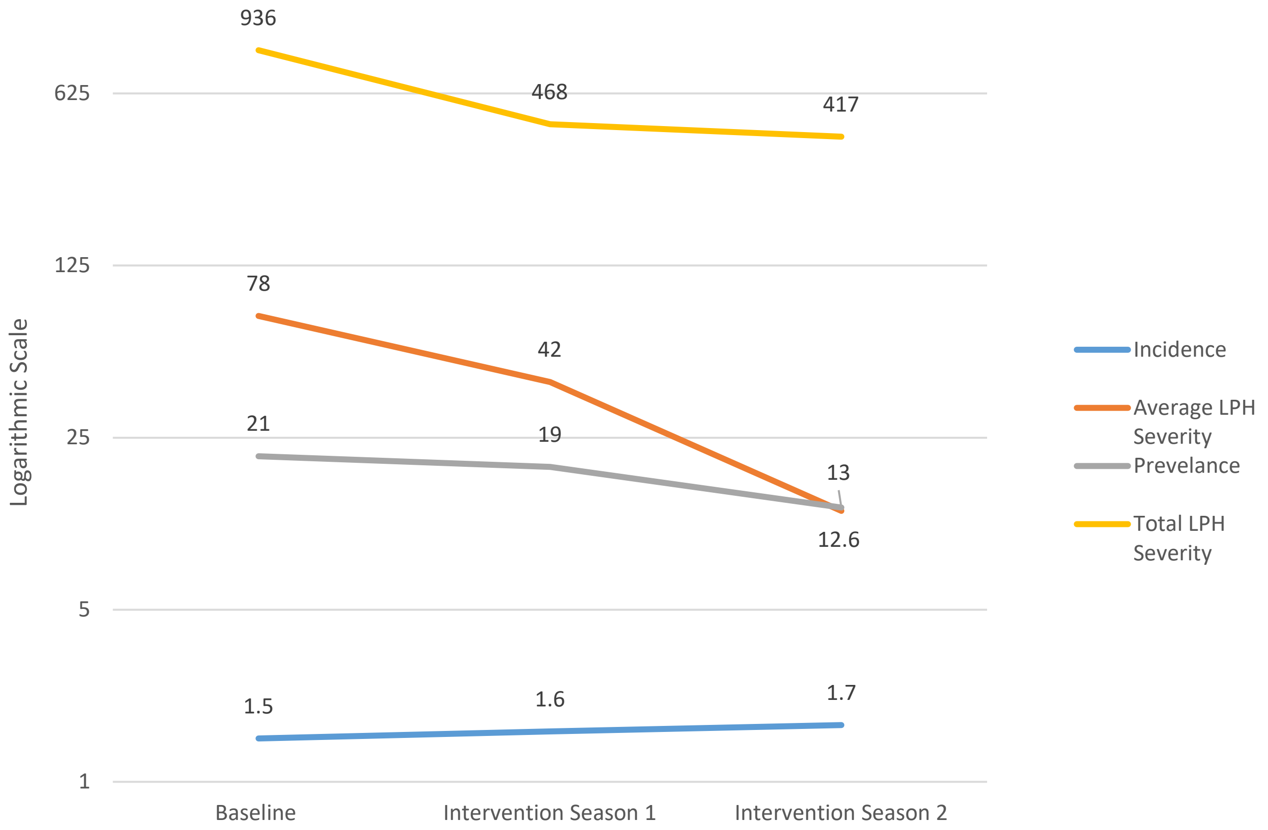


Figure 4.9 Injury surveillance data across all three seasons shown on a log scale with a base of 10

## 4.4 Summary of Results

The use of a tailored injury reduction programme aimed at reducing LPH injuries in professional rugby union was successful in reducing the total severity (936d v 417d in season 3); average severity (78d v 12.6d in season 3) and prevalence (21% v 13% in season 3). Players reported that they are confident in their ability to engage with injury reduction programmes as long as they are individualised, written by the medical team in conjunction with the players themselves and performed under supervision by the medical or strength and conditioning team. Following the intervention withdrawal, total incidence per 1000 hours exposure doubled (1.5 v 2.9 in season 4); total severity increased fourfold (417d in season 3 to 1668d in season 4) and average severity increased eightfold (12.6d v 99d). Prevalence increased to 42%. Anthropometric data did not differ significantly across the four seasons. The number of matches and GPS data regarding workload was monitored throughout. Players competed in 34 or 35 games per season throughout the study period. GPS data saw a significant increase forwards and backs average match distance, training meters per minute and forwards meters per minute in matches. This significant increases in GPS training volume (e.g. distance covered) and intensity (e.g. M/min) may explain the changes in injury surveillance data across the three seasons.

# Chapter 5 Discussion

## 5.0 Introduction to the Chapter

Following the introduction of a tailored LPH injury reduction programme within a professional rugby union team, incidence remained stable, whilst total severity (days lost) halved, average severity (days lost) reduced by 46% and prevalence reduced by 2%. The end of season anonymous review revealed players preferred their injury reduction strategies to be individualised, (i.e. tailored to them personally, considerate of their unique injury history and discussed with the player themselves). Players also reported that injury reduction is both important and expected, and that the sessions should be separate rather than integrated, delivered in the morning or pre-weights and made mandatory for all players. Finally, players identified the need for injury reduction sessions to be a quality interaction with dedicated (preferably medical or strength and conditioning) staff and supervised. In response to this feedback, an education session was delivered prior to the start of the second intervention season. This education session highlighted the injury reduction strategy for the forthcoming season and its implementation.  Following the second intervention season, total severity (days lost) fell a further 11%, average severity (days lost) fell a further 70% and prevalence reduced by a further 6%. Injury incidence rose slightly to 1.7/1000hours.

## 5.1 Discussion of Phase 1

The aim of this study was to explore the impact that tailored prevention programmes had on reducing LPH injuries. Exercise selection for the preventative program was based upon grouping the players based on their responses to running to voluntary exhaustion on six measures of hip/groin assessments. Injury data were compared from the intervention season and the previous season. No meaningful impact as a result of the intervention was found since the number of non-contact LPH injuries remained stable compared to the previous season. However total severity (50%) and average severity per LPH injury (46%) in the intervention season were both lower, when the preventative program was used, in comparison to the previous year. Moreover, total LPH injuries sustained by the non-clustered players were more severe by 50 days than clustered players. Players in this group were absent at the time of screening due to international commitments at the senior international, U20 or sevens level with some players also being absent as they transferred across from other teams. The incidence of sports injury at an international level in Wales is higher than other injury surveillance data in rugby union (98 per 1000 match hours, Moore et al, 2014), which may explain the increased injury incidence in this non-clustered group. Players outside of the regional team environment would have transitioned on to the international programme during their campaign and this may have involved the withdrawal from the injury reduction programme for the short campaign periods. This may also explain the increased injury surveillance data in this sub-group.

The prehabilitation exercises were selected on the most prominent responses of hip and groin strength assessments to voluntary exhaustion inflicted by the YoYo IR-1. They were based upon a number of EMG studies that have evaluated the muscle activation of the gluteal muscles (Serner et al, 2014), adductors (Escamilla et al, 2006), abdominal muscles (Bolgla and Uhl, 2005), abductors (Andersson et al, 1997) and hip flexors (Geiser et al, 2010).

Cluster 1, was characterised by a reduction in extensor strength and a significant increase in adductor strength post running. Whereas, significantly reduced adductor strength featured on both clusters 2 and 3. In addition for cluster 2, fatigue of the adductors co-existed with reductions in the strength of the synergistic pairings (extensors and abductors), and in cluster 3, the significant reduction in adductor strength did not accompany a reduction in the adductors synergistic pairing with the abductors.  In cluster three, the abductors strength significantly increased post running.

Previously reductions in adductor strength have been observed and explained by fatigue of those associated muscles (Roe et al, 2016). However, the observed increased adductor strength (cluster 1) and abductor strength (cluster 3) are possible compensatory strategies for fatigue during level running given that the adductors contract at toe-off and continue through to the early swing phase.  It has been shown that localised muscle fatigue affected sagittal kinematics and compensatory strategies were developed to protect the lower limb joints during toe-off and swing phases of running gait (DiStefano et al, 2009). Clinically this maybe explained as a feed forward phenomenon (Lephart et al, 2002). For example where the increases in adduction angle and adduction moment have potential to place the knee in a vulnerable position, the feed forward response would require anticipatory adjustments to muscle activation of the abductors (Chaudhari and Andriacchi. 2006) resulting in the observed increase in abductor strength post maximal running in cluster 3.

It is likely that LPH injury is the consequence of complex interactions between multiple risk factors and inciting events, thus any intervention aimed at reducing injury needs to be multifaceted and tailored to intrinsic risk factors. A small number of studies have implemented exercise-based injury prevention programs for the reduction of groin injuries however these have not tailored the intervention to the individual players, rather they have applied a one-size-fits-all intervention (Engebretsen et al, 2008; Hölmich et al, 2010).

There are a number of limitations of phase 1. Firstly, using previous season's injury data is a limitation, we are unable to say with a high level of certainty what was observed was just natural variation. It should also be noted that the results cannot be generalised to other populations and are specific to this sample of professional rugby players. The Yo-Yo IR 1 test has been shown to be a reliable measure of aerobic fitness and a useful measure of intermittent high intensity performance in a range of team sports (Atkins, 2006; Krustrup et al, 2003; Thomas et al, 2006), however its use as a specific hip fatiguing test in professional rugby union player has not been established. Therefore the specific hip muscular fatigue that the rugby players are exposed to in matches are not comparable and may be perceived as a limitation of this study. Due to time constraints only the dominant leg was assessed using the HHD, thus we were unable to examine the role of asymmetry in the risk of LPH. HHD has a number of critics who believe that HHD merely measures the testers own strength rather than the force exerted by the participants. Advocates of this argument suggest that using external restraints to hold the HHD can remove any tester bias from the measure, however these external restraints are intricate and time consuming to apply. Whilst we accept the criticisms of HHD, the reliability data from the tester is published for openness and the priority of this battery of tests was to assess hip and groin changes following fatigue in a quick and time efficient manner, using accessible equipment. To employ external harnesses or use an alternative method such as isokinetic dynamometry may have enhanced the validity of measures taken, but at the expense of reproducibility, applicability and timeliness. Finally, this phase has reported HHD scores as Kg. We did not measure lever length and so cannot present normalised scores as Newtons/Kg BW (Mosler et al, 2017).

## 5.2 Discussion of Phase 2

Twenty nine professional male rugby players completed an injury prevention and prehabilitation questionnaire as part of their broader end of season review in the final week of the intervention season 1. The key findings from the questionnaire data were that 25 of the 29 players asked felt they had performed injury prevention work in the past season and 21 players felt they would benefit from future injury prevention work. Reasons for performing injury prevention activities include enhancing player longevity, enhancing player welfare and improving team success. Reducing the financial burden of injury on the club was of less importance to players. In the previous year most players felt the injury prevention programme was medical led, followed by a combination of medical, strength and conditioning and self-led. Players reported a preference to injury prevention programmes that are tailored to the individual player rather than the same for the whole squad (one-size-fits-all). Players self-reported injury prevention 'work-ons' for the forthcoming season were identified as lumbo-pelvic-hip injury (39%), shoulder injury (30%), foot and ankle injury (11%) and cervical spine injury (9%). This compliments the injury surveillance data from the previous season for these participants which identified that foot and ankle injuries (24%), LPH injuries (15%), spinal injuries (13%) and shoulder injuries (11%) had the highest incidence in this sub-group of players. The majority of injury prevention programmes in the published literature focus on the reduction of ACL and knee injuries (e.g. PEP, FIFA 11+). The incidence of ACL and knee injuries in rugby union is comparable to other sports (Rafferty et al 2018) however rugby players in this study were not concerned with participating in injury reduction programmes in the forthcoming season, focused on reducing knee injuries. Following a season of tailored injury prevention programme for the reduction of lumbo-pelvic-hip injuries, this was still considered an injury prevention priority for the forthcoming season.

The indicative content analysis of the open ended questions identified three key dimensions.  Firstly, that this is an area that is both important and expected in an elite/professional environment. Players reported that injury prevention and prehabilitation should be mandatory, preferably a separate session (not integrated in to another session) that is either performed at the beginning of the day or pre-weights sessions. Secondly players reported that injury prevention and prehabilitation should be individualised and tailored to the player themselves, specifically to their injury history and constructed in discussion with the player. The third theme to emerge was that of ‘quality’. Players reported that they want their prehabilitation sessions to be a quality interaction, with dedicated staff – preferably medical/’physio’ led. This conflicts with an earlier question where 72% of players agreed or strongly agreed the strength and conditioning staff should lead their injury prevention programme, and 83% agreed or strongly agreed that medical staff should lead their injury prevention and 81% stated it should be a combination of medical, strength and conditioning and player led. Indicative content analysis also revealed that players believed all sessions should be supervised.

### 5.2.1 Player Awareness of Injury Prevention

All players had been involved in an injury prevention programme over the course of the season which aimed to reduce the likelihood of lumbo-pelvic-hip injuries. The specific injury prevention programme has been detailed previously (Evans et al, 2017) however it is worth noting here that the programme was fully integrated in to players gym based strength and conditioning programme and was individually tailored to the players' response to screening under fatigue using Ward's hierarchical cluster analysis. Players were not explicitly told that the aim of these exercises was to reduce LPH injuries. This may be reflected in responses with only 25 out of the 29 players reported that they had taken part in an injury prevention/ prehabilitation program. Twenty players stated that had actively engaged with prehabilitation over the past season, with nine players undecided. Twenty one players stated they would benefit from more injury prevention education. During the previous seasons' injury reduction programme, players had very high compliance (>90%), as noted by attendance to gym based sessions and training programme logs. Typically compliance in injury prevention studies is poor. Studies have reported compliance ranging from 19.4% (Engebretsen et al, 2008) to 79% team compliance (Hägglund et al, 2013). There is a myth surrounding compliance amongst practitioners that players won't conform if they believe that the purpose is merely 'injury prevention'. Unpublished, anecdotal comments from conference presentations and social media frequently portray a 'don't tell the players it's prehab - tell them it is performance training' message. This 'prehab by stealth' approach is widely adopted in practice though it appears unfounded within this study sample. Seventy two percent of players in this study want greater education with regard to injury prevention and prehabilitation and believed they would benefit from injury prevention work. Indicative content analysis also showed that players believed injury prevention to be important and expected. Why then, are we so sure that players would prefer not to engage with an activity that has potential to enhance their career longevity, improve player welfare and increase team success. The players' voice in injury prevention research is overlooked and the assumptions of the 'expert clinician' are ignorant to the players' wishes. Educating players as to the intended benefits of injury reduction strategies may enhance compliance in injury prevention research.

### 5.2.2 Individual Prehabilitation

Players commented that they would prefer tailored injury prevention programmes that are discussed with the player and also based on players' previous injury history. Kristiansen and Larsson (2017) reported similar findings in their elite soccer players. Players reported both the need for an individualised approach and feeling as though they knew their body best but would be happy to work with the medical team to develop the best possible programme for them. This finding conflicts directly with how injury prevention programmes are typically designed and administered (Soligard et al, 2004; Mendelbaum et al, 2005; Gilchrist et al, 2008; Steffen et al, 2013; Owoeye et al 2014; Finch et al, 2014; Silvers et al, 2015). In previous studies, typically the injury prevention programme is not tailored to the individual and players all receive the same intervention regardless of their specific intrinsic risk factors. In this particular study, 72% of players negatively rated the notion that injury prevention could be the same across the whole squad.

### 5.2.3 Important and Expected

According to Chan and Hagger (2012), players are motivated to engage in injury prevention programmes if the behaviour is considered a social or subjective norm, i.e. that the behaviour is perceived to be socially acceptable. Within this study, players' perceived the injury prevention programme and prehabilitation as both important and expected. Players stated they would prefer their injury prevention programmes to be separate on the schedule, rather than integrated in to other sessions. They also felt the programme should be administered before weights or at the beginning of the day. Kristiansen and Larsson (2017) found similar results within their study. Players felt that injury prevention was part of being in a performance environment and that it was only meaningful when medical staff, coaching staff and the entire organisation supported it.  This is echoed in this study, for example, one player has commented that 'there must be buy in from everyone'. It is also worth noting that players referred to injury prevention sessions as being mandatory. This perhaps links to an earlier question challenging players' motivations for taking part in such strategies. Chan and Hagger (2012) also identify that players will be motivated to engage in injury prevention behaviours if they perceive it to be a positive behaviour or players possess a positive attitude to the injury prevention behaviour. In this study, players responded positively to the rationale that injury prevention strategies improve player welfare (97% agreement), career longevity (100%) and team success (90%) whilst less than 70% believed that reducing the financial burden of injury on the team should be a deciding factor. Respondents in this study appear to conflict with Kristiansen and Larsson (2017), who reported that footballers are motivated to take part in injury reduction strategies in order to gain the opportunity to play for a larger, more prestigious club and achieve more (personal) success.

Players in this study appear more aligned to the autonomous motivation element of Deci and Ryan's (1985) Self Determination Theory – where autonomous motivation relates to a sense of volition, self-satisfaction or intrinsic values. Equally, Keats et al (2012) state that intrinsic motivation occurs where the behaviour is considered meaningful to the individual (relatedness). Finally, Chan and Hagger (2012) identified this type of motivation as a distal predictor of the intention to perform a behaviour. Using any of these theories, this self-preservation belief in injury prevention is considered a positive predictor of injury prevention intentions.

### 5.2.4 Quality

The final theme to emerge from the last open ended question was that of quality. Players wanted their injury prevention/ prehabilitation to be a quality interaction, preferably medical/physiotherapy/strength and conditioning led and supervised by dedicated staff. Whilst players also reported being happy with strength and conditioning staff involvement, dedicated medical staff were preferable in the open ended answers given. Players felt that injury prevention should not be seen as a tick box exercise and sessions should be supervised to ensure players were completing exercises correctly. This is also in direct conflict with existing injury prevention programmes. Both the PEP and FIFA 11+ involve educating coaching staff on the delivery of the specific warm up exercises. Coaching staff have no specific education or training with regards to the technical aspects of prehabilitation exercise instruction or delivery. A limitation of these studies is often the poor compliance. As mentioned earlier this can be as low as 19.4% (Engebretsen et al, 2008). What is unclear from these studies is why the compliance is so poor. It may be due to a disengagement of either the players or coaches, or both. Either way it can be argued that an unskilled coach may not ensure a quality interaction with the players during the execution of these exercises and that may result in reduced motivation to participate on behalf of the players. Chan and Hagger (2012) have cited perceived behavioural control as an important predictor of the players' intention to engage with injury prevention behaviours. The player will be *motivated* to engage if they are confident in their *ability* to engage in the injury prevention strategy. Having a dedicated staff member supervise all sessions will ensure that players are correctly performing the prescribed exercises thus enhancing players' perception of competence and therefore confidence.

### 5.2.5 Limitations

Whilst this study is unique in offering players undertaking a tailored injury reduction programme a 'voice' regarding their injury prevention perspectives, this study also has its limitations. This study only collected twenty nine professional rugby union players' anonymised experiences from one regional team. All twenty nine players were contracted to play at the same team for another season. Twenty two players from the same squad were excluded due to termination of contract, transfer to another professional club or secondment to international duty (senior and under 20s). The questionnaire was administered as part of a broader end of season review, and was thus kept brief. More in depth information could be collected via interviews or focus groups.

## 5.3 Discussion of Phase 3

The aim of this study was to investigate if continued use of the intervention resulted in further reductions in incidence, severity and prevalence. Support for the use of a tailored programme designed based upon the screening is evidenced. A reduction in total LPH injury severity (-55%), average LPH injury severity (-84%) and prevalence (-38%) was observed across two intervention seasons, when compared to a baseline season.

The combined findings for all phases of this study spanning three seasons are novel and pertinent to injury reduction in professional sport. Only one other study has followed a team across more than one season (Tyler et al, 2002) however that study only included two sessions a week for a 6 week period through preseason, after which no further testing or prehabilitation was prescribed. Tyler et al (2002) also grouped the two intervention seasons together and only reported the number and incidence of adductor strain injuries across both seasons combined, and omitted severity and prevalence data. Only one other study exists that has implemented an intervention aimed at reducing groin injuries. Holmich et al (2010) completed a cluster randomised study with 44 football teams. Twenty two teams completed a groin injury prevention programme consisting of 6 exercises performed during a standard football warm up. Twenty two teams continued with their usual training sessions. A total of 977 football players took part in the study. Results showed no significant effect of the intervention however the risk of groin injuries was reduced by 31%. Compliance was not reported in this study however the researchers concluded that the compliance of the players to perform the exercises with both the intended frequency and the intended intensity could also be a problem.

Whilst a number of intrinsic risk factors exist for LPH injuries in sport, very few studies have screened for these factors and then developed an intervention based upon the findings. Hölmich et al (2010) performed no screening as part of their study. Tyler et al (2002) was limited to only the long lever, side lie Adduction-to-Abduction ratio and crudely applied the intervention to any player found to have a ratio of less than 80%. In this study, we developed a comprehensive assessment after considering the evidence for intrinsic risk factors. Initially the screening protocol considered 6 tests (Adductor squeeze at 0, 60 and 90/90º, HHD for abduction, adduction and hip extension) this was extended to 11 tests following completion of intervention season 1 (HHD hip flexion, hamstring in inner range and 30º knee flexion, and goniometry ROM of hip flexion and internal rotation). In addition to assessing these screening tests at rest, tests were also repeated following volitional exhaustion post Yo-Yo IR-1 running test. The assessment of hip screening tests post exercise offers novel insight in to the effects of fatigue on lumbo-pelvic-hip musculature and often provided a very different clinical picture to that obtained at rest. We strongly recommend clinicians consider the players response to fatigue during screening. Unpublished injury audit data from the 2014-2015 (baseline) season showed that 26% of all injuries occurred during the 21st - 40th minute and a further 26% occurred during the 61-100th minute. When considering non-contact soft tissue injuries to the LPH region, 48% of injuries in the 2014-2015 season occurred during the 61st - 80th+ minute, and a further 28% of non-contact LPH injuries occurred in the 21st - 40th minute, thus providing a rationale for testing under fatigue.

Studies report superior preventative results with higher compliance to the preventative exercises (Gagnier et al, 2013; Hägglund, Atroshi, Wagner, & Waldén, 2013). Tyler et al (2002) and Hölmich et al (2010) do not report adherence in their studies. Within this study, players completed an average of 1.8 sessions per week across both seasons (greater than 90% compliance). Compliance can be reported in many ways but typically it is expressed as a percentage of available sessions completed (van Reijen et al, 2016). Compliance reporting is still often overlooked in injury reduction papers. Where it is reported, definitions of compliance are not always included. Steffan et al (2013) reported the effects of the FIFA 11+ warm up on injury surveillance. They classified high compliance to be where more than 48.2% of available sessions were completed and low compliance as less than 24.7% of sessions completed. Engebretsen et al (2008) reported compliance as more than 30 sessions completed. In their study compliance amongst soccer players for knee exercises was 29.2%, hamstring exercises was 21.1% and 19.4% for groin exercises. Gabbe et al (2006) examined the effect of eccentric hamstring exercises on amateur Australian footballers and reported that 46.8% of players participated in more than the first 2 sessions. Soligard et al (2008) used the FIFA 11+ warm up and reported 57.9% player compliance where high compliance involved completing 33-95% of all sessions and low compliance involved 0-14% of all sessions. Only one study has reported perfect compliance. Longo et al (2012) used the FIFA 11+ warm up in basketball players. They reported 100% compliance however they failed to explain how this was achieved or what criteria was used to determine compliance. It appears from the literature that even when high compliance scores are reported, the criteria for ‘compliance’ can be defined by a very low bar of engagement.

Phase 2 in this series reported that professional rugby union players from one regional professional team are motivated to engage in injury reduction strategies if the programmes are individualised and tailored to the player, written by medical staff in conjunction with the player themselves and performed under supervision by the medical team. Across both intervention seasons players were grouped based upon their individual responses to screening tests using hierarchical cluster analysis. The injury reduction programme for each cluster was written by a member of medical staff and shared with strength and conditioning staff. As a multidisciplinary team, the programme was then embedded in to players' strength and conditioning programmes as accessory exercises to their main strength based exercises. Each session was completed in the strength based gym session under the supervision of both the medical and strength and conditioning staff. We believe this contributed to excellent compliance to the programme (>90% across both seasons). In addition to phase 1, players were given an introductory session to the teams' injury prevention strategy prior to the start of the formalised preseason training schedule. In this session players were informed of the rationale for the LPH screening programme, the results of screening and the proposed clusters, the 'workons' for each cluster and how the programme was going to be implemented. This awareness of LPH injury reduction priority may have encouraged players to report any LPH issues to medical staff earlier than in previous years and a subsequent slight increase in injury incidence was noted (0.1/1000hours). The increased awareness and subsequent potential for earlier presentation to medical staff at the onset of LPH pain may also be responsible for the reduced total severity and average severity (-10% and -70% respectively) between intervention season 1 and 2. Increased chronicity of symptoms may lead to a worsening prognosis and so injuries that receive treatment sooner rather than later, may save considerable time loss.

In this study, injury reduction programmes were tailored to each player by cluster. In contrast, injury reduction programmes are typically developed as a generic, one-size-fits-all programme that are administered en-masse during a warm up, as was the case is Holmich et al (2010). Such approaches do not follow the principles of exercise prescription nor the preferences of athletes themselves. Large scale interventions for generic lower limb injury reduction such as FIFA 11 and the FIFA11+ (Bizzini and Dvorak, 2013) involve the implementation of a one-size-fits all warm-up aimed at reducing lower limb injuries. Two intervention studies have examined the effectiveness of the FIFA11 programme (Steffan et al, 2008; van Beijsterveldt et al, 2012) and four studies have examined the effectiveness of the FIFA 11+ in reducing lower limb football injuries (Soligard et al, 2008; Owoeye et al, 2014; Hammes, 2014; Silvers-Granelli et al, 2015). When data is pooled for both the FIFA 11 and FIFA 11+ warm up protocols a reduction in overall injury risk ratio of 0.75 is shown with an overall reduction in football injuries of 39% (Thorborg et al, 2017). When considering hip and groin injuries alone, pooled data from the previous 6 studies show a 41% reduction in injury. Within this small study, injury severity was reduced by 55% by the end of intervention season 2, and mean severity was reduced by 84%. Whilst these programmes demonstrate effective injury reduction capabilities when the data is pooled, evidence from qualitative research tells us that players do not want a one-size-fits-all approach, delivered in warm up sessions by non-medical/coaching staff (phase 2). Kristiansen and Larsson (2017) also found that professional footballers wanted an individualised approach to injury reduction developed by medical staff in conjunction with the player. Players in this soccer study felt it was disrespectful to develop an injury reduction programme without their contribution as they knew their bodies best. Whilst en-masse warm-up reduction programmes are easily administered and do not require medical staff intervention, they may not be what is desired by the service end user; the players themselves.

There is a large difference in the baseline and withdrawal season injury surveillance data. In the baseline season all players were given small, generic injury reduction programmes based upon reducing the incidence and severity of hamstring injuries. Players were asked to take part in two hamstring strengthening sessions at the end of training on day 2 and 5 of the training week during preseason. During these sessions players were asked to complete 3 sets of 6 repetitions of a single leg glute:hamstring bridge and 3 sets of 3 repetitions of a Nordic hamstring curl. Where the player was unable to complete the Nordic hamstring curl, they were advised to complete 3 sets of 3-6 repetitions of a double leg Swiss ball rollout, progressing to a single leg Swiss ball roll out and then finally, Nordic hamstring curls. During the season, players completed one set of hamstring injury reduction strengthening as part of their normal posterior chain exercises. No other programme of prevention was in place for the lower limb during the baseline season. In the withdrawal season, all injury reduction strategies were removed, no generic strategies were put in place.

The GPS data across all three seasons are listed in table 3.7. No significant differences were found across the three seasons for forwards and backs average distance in training, and backs m/min during matches. In the four year period covering this study, coaching staff have changed on 3 occasions. The region was also taken over by the national governing body in the withdrawal season. Each coach and owner will have a specific style of play, ethos and approach, however the same High Performance Manager was in post across all seasons with a remit to set the workload, rest days and schedule for the players, thus minimising the risk of any sudden spikes in training volume. Training workload has been identified as a potential risk factor for injury. Windt and Gabbett (2017) state that workload increases relate to increases in sports injuries. However, the research in this area only really considers workload in relation to an acute (1week) versus chronic (4 week) ratio. No study has examined the season long accumulative increase in workload. Training related adductor injuries in rugby union have been reported to be high at 0.8/1000 hours exposure (Brooks et al, 2005 a&b).

There was a significant change in metres per minute ($m.min^{-1}$) in training and average distance covered during games for forwards and backs across the three seasons. This implies that whilst players were not covering greater distances in training, significant increases in m/min in training were likely to be the results of increased high speed running or sprinting activities. Whilst LPH injuries are common in many sports that require rapid acceleration and deceleration, sudden changes of direction and kicking (Evans, Williams and Hughes, 2017) it is not clear from the GPS data that an increase in any of these activities were noted in across the study period. The significant increases in average match distance covered for forwards and backs across the three seasons may not relate to an increase in acute: chronic workload as Gabbett describes it, however it does mean an increase in players exposure to potentially inciting/injurious events during training. This may explain the changes observed in injury incidence (+71%), total severity (+300%), average severity (+685%) and prevalence (+29%) between intervention season 2 and withdrawal season. The accumulative increase in training distance may also contribute to an increase in fatigue which will negatively alter intrinsic risk factors and subsequently increase injury risk (Windt and Gabbett, 2017). These may offer a possible explanation for the differences in injury surveillance data beyond the effect of withdrawing the injury reduction intervention. That said, the magnitude of increase in total distance covered in training was more than metres per minute and coincided with a reduction in match related workload data, therefore it could be argued that the workload served to induce adaptation rather than fatigue, and that this would positively alter intrinsic risk factors and thus lower the injury risk (Windt and Gabbett, 2017).

### 5.3.1 Phase 3 Study Limitations

We acknowledge a number of limitations of the present study. In addition to the limitations outlined in phase 1, it should also be noted that the results cannot be generalised to other populations and are specific to this sample of professional rugby players who train on an artificial surface and play predominately on grass. No follow-up testing was completed to review the effectiveness of the intervention the hip and groin tests conducted at rest and post maximal running, and despite the exercise selection progressing over time to include more complex and demanding movement tasks we are unable to conclude that the tailored interventions were effective at altering intrinsic risk factors for LPH injury. Risk factors for sports injury are temporal and can vary over time (Verhagen et al, 2018). The use of a one-off preseason screen offers nothing more than a static screenshot. Screening should be repeated at regular time points throughout the season and combined with other monitoring variables to regularly assess players' intrinsic risk factors. Again, due to time constraints only the dominant leg was assessed using the HHD, thus we were unable to examine the role of asymmetry in the risk of LPH. Range of movement is another element often included in screening research that was not considered in phase 1. Hip flexion and internal/external rotation have been identified as possible antecedents to LPH injury in Baseball (Li et al, 2015) Gaelic football (Nevin & Delahunt, 2014) and Soccer (Tak et al, 2016) and were added to this battery of tests, however their addition to this protocol did not appear to add significantly to the screening results or the intervention development and decision making. The addition of the 5 further tests (Hamstring strength at inner range and 30$^{o}$, hip flexor strength and hip flexion and internal range of movement) added an additional 30 minutes of testing time to the battery but appeared to offer little in new insight from the original 6 tests. Significant differences were noted between cluster 1 and cluster 2 for hamstring strength in both knee flexor positions, hip flexor strength, hip abduction and adduction strength and hip internal ROM, however the intervention developed for each cluster based on the findings of the screening battery changed little in response to these new screening test results. The intervention administered to cluster 1 in both intervention seasons involved targeting low threshold deep hip rotator cuff muscles and high threshold Gluteus Maximus strength. The intervention for cluster 2 across both phases involved lower abdominal control and adductor strengthening. The additional 5 tests did not change the clinical picture sufficiently enough to warrant a change to the interventions applied, therefore it could be argued that the additional time spent on these tests had no bearing on the clinical decision making process taken.

## 5.4 Summary of Discussion

The argument presented in this discussion is that the introduction of a tailored LPH injury reduction programme coincided with a reduction in total severity and prevalence across the initial three seasons (baseline, intervention 1 and intervention 2) of the study. A significant reduction in average severity was noted between baseline season and intervention season 2, and intervention season 1 compared to intervention season 2. No causal relationship can be established, however this study proposes that the LPH injury reduction programme positively influenced the total injury severity, average severity and prevalence in one professional rugby union side by reducing the intrinsic risk factors that may predispose a player to a LPH injury.

# Chapter 6 Practical Applications

## 6.0 Introduction to the chapter

A number of practical applications are derived from this study. This chapter will provide a succinct overview as to the potential uses of the study outcomes to the practitioner facing their own sports injury problem. This chapter will also consider the impact and value of the data derived to the researcher, other practitioners and the team themselves.

## 6.1 Practical Applications from Phase 1

The use of hierarchical cluster analysis may provide valuable information on how to group players to overcome logistical difficulties in implementing individualised tailored injury reduction programmes. A tailored injury prevention programme based upon changes in hip and groin strength under fatigue may reduce injury severity and prevalence in professional rugby union players compared to a generic exercise programme

## 6.2 Practical Applications from Phase 2:

Players questioned as part of this study demonstrate preferences for injury reduction programmes that are individualised (e.g. tailored to the player, considerate of their injury history and proposed in collaboration with the player themselves) and of quality (e.g. based on quality interactions with dedicated staff who are preferably medical, and who can supervise sessions). Players also reported that injury reduction strategies are both important and expected in the professional rugby environment. This is contrary to the current approaches adopted within the literature and perhaps offer some explanation as to the lack of empirical data demonstrating the effectiveness of exercise interventions for the reduction of injury burden.

## 6.3 Practical Implications from Phase 3:

Using hierarchical cluster analysis to tailor injury reduction programmes based upon screening hip strength tests post fatigue running appears to be a suitable alterative to en-masse, one-size-fits-all injury prevention programmes for rugby union players and complies with player preferences for an individualised approach. The addition of 5 new tests to the battery offered very little in the way of further clinical insight, however the player education session may have contributed to players reporting LPH injury problems earlier, thus reducing the average severity significantly when compared to baseline and intervention season 1.

## 6.4 The Impact and Value of the Research to the Researcher

When complete members of an organisation seek to inquire in to the working of their own organisational system in order to change something in it, they can be understood as undertaking insider action research (IAR) (Coghlan, 2014). IAR offers a unique perspective on systems, precisely because it is from the inside. The context of IAR is the strategic and operational setting that organisational members confront in their working lives (Coghlan, 2014). IAR is commonly undertaken by practitioners who are enrolled in practitioner programmes such as the Professional Doctorate – insider action researchers (IARs). According to Coghlan (2014), when the research involves taking action or leading change, then IAR is an appropriate way of framing it and writing about it. Very few papers exist on the role of IAR in sport, and none exist that employ IAR in sports injury prevention. Traditionally, there has been a general neglect of this research approach due to two traditional assumptions. Firstly, that being native is inimical to good research, and secondly, that researching in action does not provide sufficient methodological rigour for generating valid knowledge (Coghlan, 2014). Personally I felt as though being an IAR gave me a unique perspective on the sports injury problem at this particular professional rugby team. As mentioned previously, the insider action researcher is an interventionist, as contrasted with the insider researcher who focuses on observation and analysis only and does not aim to change anything (Alvesson 2003). A number of challenges have been noted of this type of research approach. Firstly, gaining access to the information can be difficult; secondly, preunderstanding and potential for making assumptions as an insider to the organisation; thirdly, the potential conflict of role duality; and finally the delicate management of organisational politics.

The IAR is immersed experientially in the situation and balances both professional and academic roles. Where the IAR is a professional, with the moral, ethical and professional requirement to actively prioritise the wellbeing of service users, this must be balanced with the ongoing need to maintain a positive relationship with professional peers, at the same time as undertaking the research study (Nylan et al, 2016). As a Graduate Sports Therapist, I am bound by the professional standard of conduct, performance and ethics (Society of Sports Therapists, 2019) which outline my professional obligations to my patients. Throughout my time at the professional club I have always worked in academia as a Senior Lecturer and subsequently as a Professional Doctorate student. Players have always been aware of my role duality.

### 6.4.1 Access

Whilst the IARs is already a member of the organisation, they may not have access to the specific parts of the organisation needed to conduct their research. Sometimes the researcher may be restricted due to limited access to other departments, or because there is a hierarchical restriction on accessing information. This may place the IARs at a disadvantage when compared to an external/outsider researcher. The advantage of working as a Head of Rehabilitation, in a small high performance environment meant that primary and secondary access (e.g. to documentation, data, people and meetings) was not an issue, as the researcher was the creator and collator of the data required. The IAR may be given complete access to the required information in order to improve practice within the organisation, however when seeking to publish their findings they may encounter a particular issue relating to access of information for audiences outside of the organisation. The issue of access to information is therefore embedded in the challenges of role duality and organisational politics.

### 6.4.2 Pre-Understanding

Preunderstanding refers to 'such things as people's knowledge, insights and experience before they engage in a research programme' (Gummesson, 2000). The knowledge, insights and experience of the IARs not only applies to the theoretical understanding of the organisation dynamics but also their lived experience of the organisation (Coghlan, 2014). Personal experience and knowledge of their own system and job are a distinctive pre-understanding for IARs. Whilst preunderstanding brings the researcher closer to the data, it also has its disadvantages. The IAR may assume too much and so not probe as much as if they were outsiders or ignorant of the situation (Coghlan, 2007). The IAR may find it difficult to step back and distance themselves from the organisation in order to assess and critique it. Closeness and familiarity have a tendency to inhibit enquiry. According to Coghlan (2014), pre-understanding for IAR involves building on closeness and achieving distance. As an IAR, I found the closeness and familiarity to the organisation a positive influence on the research. As mentioned previously, I had worked at the professional men's team for almost 5 years before starting the Professional Doctorate. Prior to working for the senior men's team, I had previously worked in other sporting organisations and had even worked in the academy for this professional men's team. I had worked with some of the players in the academy role before re-joining them later in their career with the senior team. For players under the age of 18, I would assume the role of 'in loco parentis' during training and home and away matches. I also fulfilled the role of Talented Athlete Support Service officer. All of these experiences brought me closer to the players than an outsider researcher would perhaps be. I did not see this as a disadvantage, in fact I believe it permitted open and honest dialogue with players regarding their injuries (LPH or otherwise). However, there is potential for conflict within any sports performance structure. Collins et al (1999) have highlighted role conflict and confidentiality in multidisciplinary athlete support programmes. Figure 6.0 overviews the basis of role conflict. As a medical professional working in an athlete support programme, I am employed by the team/club to provide a service to its players. In a private practice scenario, I would have a service level agreement with the patient to provide medical provision, e.g. diagnosis and treatment, and this would clearly define the boundary of confidentiality. However in the professional sports team environment the service level agreement is with the team not the individual players and thus there is an extended boundary of confidentiality that includes stakeholders within club e.g. coaching and conditioning staff. Players may not feel comfortable in discussing issues with me for fear of specific information being passed to coaches, which may be viewed negatively or influence selection and/or contract decisions. As Leary (1994) points out, this process is neither dishonest nor Machiavellian but rather is an inevitable feature of high performance group dynamics. All players are made aware of the extension to the boundary of confidentiality and give consent for information to be passed on to other members of the high performance team. This is standard practice in elite sport and I feel has not impacted on the disclosure (or non-disclosure) or access to, information within this study.

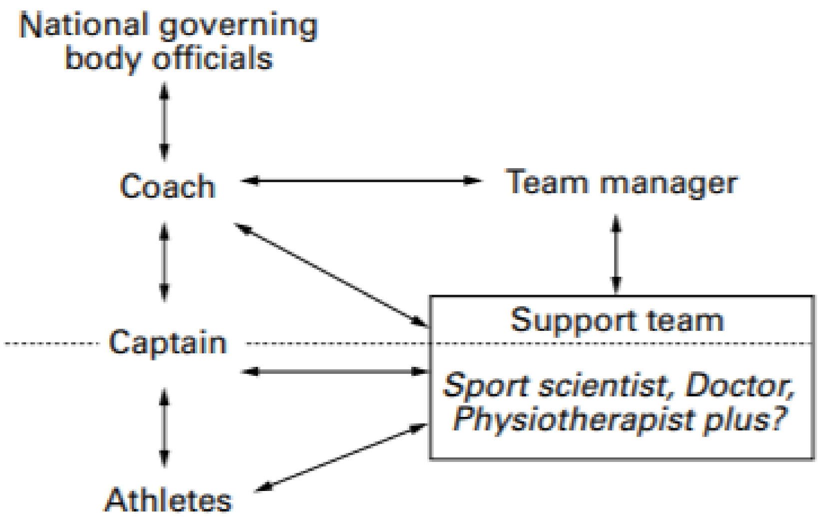


Figure 6.0. The basis of role conflicts between athletes, officials and support teams (Collins et al, 1999).

### 6.4.3 Role Duality

The IAR researcher may encounter role conflict and find themselves 'caught between loyalty tugs, behavioural claims and identification dilemmas' (Coghlan, 2007). The organisational system may not have unified expectations of the action research project and so there may be ambiguities and conflicts as different members or factions hold different expectations of the role the IAR will play. At the same time, the IAR may have expectations of what their role is or what they want it to be, which may or may not accord with the role as is understood by the organisation (Coghlan, 2014). This conflict may lead to an experience of role detachment, where the IAR begins to feel as an outsider in both roles. Role duality was never an issue throughout this study. My role as Head of Rehabilitation included responsibility of injury reduction/prevention strategies. This project and its intervention would have taken place irrespective of my enrolment on to the Professional Doctorate as it was considered my role to do so. The writing up of the project was external to this role and thus a dichotomy of roles was clear from the outset.

### 6.4.4 Organisational Politics

According to Coghlan (2014), political dynamics are an integral part of organisational life. Any form of action (and research) in an organisation will have its political dynamics. These dynamics can undermine research endeavours and block planned change. Coghlan and Brannick (2014) use the term political entrepreneur to imply a behavioural repertoire of political strategies and tactics and a reflective, self-critical perspective on how such political behaviours can be deployed. Political entrepreneurship requires the ability to achieve congruence with one's values set and the value set of action research and to find ways to exploit learning opportunities within the organisation. Value congruence was never considered an issue in this study. The High Performance Manger set a culture of being willing and open to change, and that empowered staff to consider possible improvements to service delivery. We were encouraged to find better ways of working and to improve our performance metrics – as long as it did not cost anything!

### 6.4.5 Ecological Validity

In research, the term ecological validity implies that the study methods and setting approximate the real world with what is being examined (Brewer, 2000). Finch (2006) highlighted the current bias for conducting studies under laboratory conditions in clinical settings and artificial environments. In stage 4, Implementation, of the TRIPP model, Finch (2006) states that typically a study provides staff, equipment, expertise and time, which are often incentivised, to encourage participation in sports injury prevention research. After the study has finished none of these influences or resources are available and the organisation or club are simply unable to sustain or maintain the intervention, thus the research does not translate in to real world practice and make a meaningful and impactful change in clinical practice. Hanson et al (2014) also highlighted the research-to-practice gap stating that the process of implementation, sustainability and population impact are frequently overlooked. This leads to a gap in the transition between researching what works and how to make it work, i.e. efficiency and effectiveness. Both Hanson et al (2014) and Glasgow et al (2008) have highlighted that contextual complexity is often missing in injury prevention research. The TIP cycle (O'Brien et al, 2018) also discusses real world implementation challenges. In stage 1 (evaluation) the authors recommend that sports teams consider how sports injury prevention programmes are currently being delivered. In stage 2 (identification), teams should consider the barriers and facilitators to delivering injury prevention programmes. Finally, in stage 3 (intervention) the researcher should focus on the content and delivery of the injury prevention strategy. The TIP cycle reflects the nature of real-world injury prevention. The success of this study lies in its simplicity. A single researcher completed the screening in a relatively short period of time (60-90minutes) with a small amount of relatively inexpensive equipment (Sphygmomanometer, hand held dynamometer and a goniometer). Other methods of assessing strength at the hip and groin have been reviewed in chapter 2, but are costly and time consuming and are not proven to be superior to the methods used in this study. Hierarchical cluster analysis permitted a quick turnaround between collecting large amounts of raw screening data and the identification of tailored injury prevention groups. The development of three/four injury reduction programmes was also time effective. In both intervention seasons, the time delay between raw screening data collection and implementation of the first tailored injury reduction session was under 72 hours. There was no reliance on outside influences or resources to complete this project. As mentioned previously, Klugl et al (2011) highlighted the paucity of implementation studies and the wide gap that exists between our knowledge of effective prevention programmes and our ability to successfully implement them. They highlighted that less than 2% of studies examined the effectiveness of prevention programmes in a real world context. Klugl et al (2011) cited the potential difficulty of these studies to perform as a possible reason for their scarcity. I disagree with this notion. This study is a case in point. I also believe practitioners are undertaking real world meaningful research in the area of sports injury reduction but are unable to or reluctant to, place their findings in the public domain. To do so may give away a competitive advantage.

### 6.5.5 The Prevention Paradox

As mentioned in chapter 1, Roses' (1981) Prevention Paradox states that a preventative strategy that concentrates on high-risk individuals may be appropriate for those individuals, as well as being a wise and efficient use of limited medical resources but its ability to reduce burden of disease (injury) in the whole community tends to be disappointingly small. The rationale for an en-masse vaccination strategy for sports injury prevention lies within this paradox. The most common types of injury sustained in sport are generally the less severe injuries. More players sustain low to moderate severity injuries than high severity injuries. It therefore makes sense to divert resources to this large section of the population/community, where, in absolute terms, the preventative approach will benefit more athletes. However, LPH injuries are both common and severe in rugby union. In Welsh International rugby union the incidence is very high at 21/1000 match hours (Moore, Ranson and Mathema, 2015) with extended periods of time loss. In this study, baseline season data showed that LPH injuries had an average severity of 78d ± 126d. This also overlooks the 'tip of the iceberg' scenario where at any given time point, a larger population of players continue to participate despite having groin-related complaints with associated impairments or reduced performance (Walden, Hagglund and Ekstrand, 2015; Haroy et al, 2017; Thorborg et al 2017a & b). The paradox asserts that a measure that brings large benefits to the population/community offers little to each participating individual. When injuries are both common and severe – as in the case of LPH injuries, there needs to be a moral argument for prevention. Previous history of hip and groin pain is the most commonly reported intrinsic risk factor for future hip and groin injury. Studies report between 2.6 and 7.3 times increased risk for players in team sports with a previous history (Arnason et al, 2004; Gabbe et al, 2010; Engebretsen et al, 2010; Verrall et al, 2007). As an intrinsic risk factor, previous history is considered non-modifiable. Once a player has sustained that injury they are at increased risk and that cannot be removed. Also consider the young player who sustains an injury that has the potential to keep them out for 2 months + (78d ± 126d). This injury may occur during a critical point in the players' development and see a rival for their position move up the depth chart and move ahead of them in the pecking order. For an untested player, this could mean the difference between subsequent contract and unemployment. Finally, consider the older player who is forced to retire as a result of their injury. These non-normative transitions result in a more difficult or stressful transition as it is unlikely that the athlete would have had an opportunity to prepare or plan methods of coping (Stambulova et al, 2009). With a career-ending injury, an athlete has to cope with the injury, and once the severity of the injury and its ramifications on their career have become evident, the athlete also needs to approach the rehabilitation process knowing that return to sport is not the overall rehabilitation outcome, whilst also dealing with the impending retirement and career adaptations (Arvinen-Barrow et al, 2017). Typically reactions to a career-ending injury include confusion, anger, frustration and isolation (Brock & Kleiber, 1994). Other reactions including feelings of loss, depression, sadness, negative self-identity and reduced self-esteem (Stoltenburg et al, 2011). Given the sub-groups of players at the professional club used within this study (Chapter 1), the priority for injury reduction had to be tailored to the individuals rather than whole community mass vaccination.

### 6.5.6 Dissemination

Initially, phase 1 results were submitted to UK based conferences (British Association of Sport and Exercise Sciences Conference, and the UK Strength and Conditioning Conference) and were accepted as poster presentations. I have also presented the findings of the study as a keynote address to an international Sports Medicine Conference and at the professional body (Society of Sports Therapists) annual conference and University Forum. The results of phase 1 of this project were then submitted to publication in a peer reviewed sports medicine journal (Evans, Williams and Hughes, 2017). Phase 2 will be submitted for peer review publication this summer. Phase 3 will not be submitted for publication until the current medical staff have moved on from the club, given the extent of the increase in injury surveillance data in the withdrawal season. I have been invited to deliver guest lectures on these projects at other Higher Educational Institutions to both Undergraduate and Postgraduate Sports Therapy and Strength and Conditioning courses. I have also delivered in-service Continuing Professional Development (CPD) sessions to national governing bodies and professional sports teams. Following on from this project I am also involved with a prospective, multi-season LPH screening programme with a national governing body in rugby union. In this project we assess LPH strength in professional rugby union athletes throughout the year and across competitive rugby seasons and provide feedback on results. A summary of the dissemination work is provided in table 6.0.

Table 6.0 Summary of the dissemination of findings from this thesis.

| Dissemination activity | Example |
|---|---|
| Conferences | BASES conference<br><br>Society of Sports Therapists annual meeting presentation<br><br>UKSCA conference (poster prize)<br><br>Pain to Performance Keynote address<br><br>Society of Sports Therapists University Forum presentation |
| Publications | Bourne, M.N., Williams, M.D., Jackson, J., **Williams, K.L.**, Timmins, R.G., PIzzari, T. (2019). Pre-season hip/groin strength and HAGOS scores are associated with subsequent injury in professional male soccer players. *Journal of Orthopaedic and Sports Physical Therapy*. In press.<br><br>**Evans, K.L**., Hughes, J., & Williams, M. D. (2018). Reduced severity of lumbo-pelvic-hip injuries in professional Rugby Union players following tailored preventative programmes. *Journal of Science and Medicine in Sport.* 21 (3), pp. 274-279. DOI: https://doi.org/10.1016/j.jsams.2017.07.004<br><br>**Evans, K. L**., & Williams, M.D. (2017). The effect of Nordic hamstring exercise on hamstring injury in professional rugby union. *British Journal of Sports Medicine*, 51 (4), pp.315-316. DOI: https://doi.org/10.1136/bjsports-2016-097372.84<br><br>Huggins, S., Davies, N., **Evans, K.L**., & Williams, M.D. (2017). Nordic hamstring exercise strength changes over a season in academy footballers. *British Journal of Sports Medicine*, 51 (4), pp. 331. DOI: https://doi.org/10.1136/bjsports-2016-097372.124<br><br>**Evans, K.L** & Williams, M.D. (2017). Association between hand-held dynamometry measures of hamstring strength and force obtained from the Nordic hamstring exercise. *British Journal of Sports Medicine*, 51 (4), pp. 316. DOI: https://doi.org/10.1136/bjsports-2016-097372.85 |
| Knowledge Exchange | Undergraduate and post graduate teaching at other HEIs<br><br>In-service CPD/knowledge exchange sessions in professional football, academy football, professional ice hockey and Olympic sports.<br><br>Advised on the development of commercial testing device for assessing hip/groin strength in conjunction with commercial partner |
| Future Research | Currently undertaking a longitudinal research project with a national governing body for rugby union overseas, that involves the testing and monitoring of players hip/groin strength and injury surveillance. |

### 6.5.7 The Impact and Value of the Research on the Researcher: A Summary

To summarise this section, I believe this research has contributed to the existing sports injury reduction literature.  Medical teams do not need an army of researchers with expertise, expensive resources and time. Medical teams can screen their players using a simply battery of tests, completed quickly, with reasonably inexpensive equipment by an army of one. Large amounts of data can be handled and turned in to meaningful information in a short space of time using Wards Hierarchical Cluster Analysis. This will allow practitioners to group players in to tailored clusters so that staff are not left with the decision of a one-size-fits-all intervention or the unmanageable option of 50 individual programmes. There is a half-way option that allows practitioners to tailor interventions to players who exhibit similar responses to fatigue. Interventions must evolve and adapt and most importantly must be sustainable. As an insider action researcher, the players deserve to be treated as individuals and deserve to be given every opportunity to develop robustness and resilience to potentially injurious events. The development of a professional relationship with players can also empower players to give their opinions freely, which is useful when considering the players voice in injury reduction programme development.

### 6.5. The Impact and Value of the Research to other Practitioners

In addition to the comments made above, a few take-home messages arise from this study which should be emphasised for other sports injury reduction practitioners. The notion that research should be ecological in nature to permit translation to real world practice is a strong recommendation from this study. You are probably already doing a considerable amount of work in this field with your sports team. There is a paucity of literature on sports injury prevention in the real world setting so I would encourage you to share and disseminate your findings.

Secondly, before you implement a screening programme, consider its viability and sustainability. Select your tests based upon real world practical implementation considerations rather than gold standard. In this study, quick, easy to administer tests were used so that they could be conducted for example, in under an hour (testing 28 players) by one person. The methods used aren't without their critics, e.g. HHD and other researchers have highlighted that the test protocol could have been improved. However, the other options were not viable due to timing or cost restrictions so instead, we ensured we were reliable with our measures and conducted the testing nevertheless. If the idea that screening is too costly, time consuming or requires expertise beyond your clubs capabilities, that it becomes a barrier to your injury reduction project, you may consider collaborating with a research team, perhaps at a local university. However, you must be mindful that whilst these influences and resources are in place you may reap the rewards of the data they derive, once the study is over you will be left with unsustainable project. You may be better off using a smaller battery of tests that you are easily able to administer than relying on outside influences to organise and run your injury reduction strategy.

The third point I'd like to emphasise is that any screening should not only be done at rest. Considering changes pre and post fatiguing exercise, such as running based test for the lower limb, offer an insight in to players' strength characteristics which can better mimic the mechanism of non-contact soft tissue injury. Non-contact soft tissue injuries are frequently cited as occurring in the second and fourth quarter of running based team sports (Rahnama, Reilly and Lees, 2002; Nagle et al, 2017). In this study, reassessing players after volitional exhaustion highlighted a number of outliers that weren't obvious at rest. For example, in intervention season 1, Cluster 2 showed moderate reductions across all tests as expected, however Cluster 1 demonstrated a reduction in hip extensor strength and an increase in adductor strength post running and Cluster 3 responded with a reduction in adductor and extensor strength whilst increasing abductor strength. The interventions administered would have been completely different had they been written from baseline data, rather than based upon changes due to volitional exhaustion. Eighteen players in Cluster 2 may have responded well to a generic adductor strengthening programme, however the 10 players in cluster 1 and 3 needed a more specific intervention as their response to fatiguing running was atypical. This may be as a result of a feed forward phenomenon (Lephart et al, 2002), but it is unlikely that these players would respond in the same way to Cluster 2 if they were given a generic programme. At the very least, practitioners should identify the outliers in any screening tests, i.e. the players who are considerably stronger or weaker than expected, (or where normative values do not exist, perhaps the practitioner can consider the mean and median data from the same cohort) and players who do not respond to a test stimulus in the predicted way. Outliers can be detected using simple graphical presentation of the data such as scatterplots and boxplots. This is not a time-consuming exercise but may alert practitioners to players who may otherwise have gone ‘under the radar’ and will allow you to focus attention, resources and expertise on a small group of high(er) risk players.

Finally, I would encourage practitioners to consider a tailored approach, over using a one-size-fits-all intervention, even if you are working with a large squad. Phase 2 of this study questioned players’ perspectives on injury reduction programmes and it was clear from the findings that players wanted their programmes to be individualised and tailored. Players also reported that injury prevention was important and expected, so that player welfare (97% agreement), player longevity (100%) and team success (90%) could be enhanced. I would encourage practitioners to question players’ preferences in order gain a better understanding of players’ motivation or intention to engage with injury reduction strategies. This in turn may, maximise compliance which has frequently been cited as a vehicle to superior preventative results (Gagnier et al, 2013; Hägglund, Atroshi, Wagner, & Waldén, 2013). It was also clear from phase 3, that telling players about the screening results, planned intervention and implementation logistics of the injury reduction strategy is important. Anecdotally, as a profession we often hide injury reduction strategies from our players by labelling them ‘performance training/enhancement’, however our players are open to the idea of explicit injury reduction strategies so we should not feel obliged to use ‘prehab by stealth’. ‘Decision makers must always evaluate the benefits and risks, inconvenience and costs associated with alternative management strategies and in doing so, consider their patients’ values and preferences (Haynes et al, 1996).

In this study, the easiest intervention to administer would be a 'Tyler et al (2001) style' adductor strengthening programme, or to add in one additional exercise to the players warm ups (e.g. Copenhagen adductor strengthening exercise, Harøy et al, 2017). This may have been adequate for a large group of middle percentile players; the moderates, as mentioned above, but it may not have benefited players in the outlying clusters. The use of Wards Hierarchical Cluster Analysis was exceptionally useful in grouping players within this study, in a timely manner. It would not have been possible to consider the data without the use of this statistical approach. To exemplify, in intervention season 1, 336 data sets were collected (28 players, 6 tests, pre and post running) and in intervention season 2, 880 data sets were collected (40 players, 11 tests, pre and post running). This data was collected on a Friday with preseason starting on the Monday. This statistical tool made it easy to look for patterns and trends in the data that ultimately group players for injury reduction interventions.

## 6.6 The Impact and Value of the Research to the Professional Rugby Union Team

In terms of the value and impact of the research study on the team itself, we will consider team success and financial implications of the injury burden.

Team success across the three seasons investigated identified that during the baseline season, the team finished 9$^{th}$ from 12 in the domestic league. The team also made the European Challenge cup semi-final. In intervention season 1, the team finished 10$^{th}$ from 12 in the league and again reached a European semi-final, narrowly losing to a big-budget French rugby team. In intervention season 2, the team finished 11$^{th}$ from 14. We therefore, cannot state that this study had any influence on team success.

The impact of the study on the financial injury burden can only be presented based upon the overall player wage bill and the percentage of player days lost due to LPH injury (relative to total player days available). I cannot report the individual cost of each LPH injury based upon a players' individual salary as this is obviously confidential and players have not consented to their contractual information being used in this way.  A salary cap of £3.5million was introduced to all Welsh Regional Rugby teams in the 2011/2012 season. This salary cap was increased to £4.5million for the 2016/17 season. We will assume that this professional rugby union team adhered strictly to these player wage bill cap for the purpose of the subsequent analysis. In the baseline season, total severity of LPH injuries (days lost) equated to 5% of the total player days available. This equated to an estimated 'sick pay' of £175,000. In intervention season 1, total days lost to LPH injuries equated to 2.5% of total player days and is estimated to have cost the region £87,500 in 'sick pay'. In intervention season 2, the total estimated cost of LPH injuries was £59,500 (1.7% of total days lost). The overall effect of the intervention across two seasons could be reported to save the professional rugby business in excess of £200,000. When we consider the impact of the intervention on prevalence (percentage of squad unavailable for selection), a similar picture emerges. In the baseline season, prevalence equated to £735,000 of the total wage bill. In intervention season 1, prevalence equated to £665,000 and in intervention season 2 it equated to £455,000.

Whilst I accept this method of calculation may not directly reflect the financial impact of injury based upon individual player salary, it does provide a general reflection of the cost of LPH injuries in one professional rugby union side. The money saved in the two intervention seasons would cover the cost of a new player signing in a key position such as front row or outside half. When team success is generally low, such signings can make a difference. Can any rugby business afford to overlook the importance of low cost injury reduction strategies, such as the one presented in this study.

# Chapter 7 Conclusions

The aim of this study was to develop, implement and explore the efficacy of a tailored LPH injury reduction programme based upon the players' unique set of individual intrinsic risk factors, in one professional rugby union team across multiple seasons. The impact of the intervention on injury surveillance data was measured. A secondary aim of the study was to examine the players' perceptions of injury reduction strategies and determine their preferences for implementation and delivery.

In this thesis we have been able to implement the full sequence of prevention (van Mechelen et al, 1987) in a professional rugby union team across four seasons. From the three study phases we can conclude that:

- Screening for intrinsic risk factors is possible with limited staff, resources and time. In this study, forty players were screened on 11 tests in under 90minutes at the start of preseason. This testing was completed by a single member of staff.

- Data derived from screening should consider changes to baseline data following fatigue. The addition of screening pre and post Yo-Yo intermittent running test in this study was novel and added new insight to players' responses to fatigue on hip strength measures.

- Screening data is only useful if it is interpreted and actioned in a timely manner. The use of Hierarchical Cluster Analysis may be a useful for tool for practitioners looking to establish groups from patterns and trends in large amounts of screening data. In this study, time from raw data collection to intervention implementation was 72hours.

- Researchers should consider employing an insider action research approach to examining the effectiveness of injury reduction programmes, especially when looking for a way to overcome the research-to-practice gap highlighted in the literature.

- Players should be considered stakeholders in the injury reduction programme and the implementation of the ‘sequence of prevention’. Players from this study indicated that they wanted any injury reduction programme to be tailored to them and discussed with the player directly.

- Players in this study want injury reduction programmes that are individualised and tailored to them, delivered as a separate, supervised sessions by dedicate medical staff. Players believe injury reduction is important for player welfare, player longevity and team success. Understanding players’ preferences may increase compliance, which is often noted as a limited factor to the effectiveness of injury prevention programmes.

- Implementation of tailored injury reduction exercises, delivered during lower limb strength and conditioning sessions as auxiliary exercises to strength based movements permitted excellent compliance (>90% across two intervention seasons).

- Injury reduction programmes should be sustainable. Results from this study demonstrate that implementation of the injury reduction programme over two seasons saw a significant reduction in average severity, and reductions in total severity and prevalence.

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# Appendices

# Appendix 1

## Systematic Literature Review Search Strategy

**Medline**

(adductor* or groin or inguinal or pubalgia).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] AND (athlete$ or sport$ or athletic).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] AND (pain or injur* or athletic injur* or sport injur*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] AND (strength training or resistance training or exercise or weight lifting or weightlifting or rehabilitation or therapy or treatment or prevent*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]

**PubMed, SPORTDiscus, Web of Science**

(adductor* OR groin* OR inguinal OR pubalgia) AND (athlete* OR sport* OR athletic ) AND (pain OR injur* or athletic injury* OR sport injur*) AND (strength training OR resistance training OR exercises OR weight lifting OR weightlifting OR rehabilitation OR therapy OR treatment OR prevent*)

**Cochrane**

("athlete" or "athletes" or "sport" or "sports" or "team sport" or "team sports") AND ("hip" OR "inguinal" OR "groin" OR "groins" OR "adductor") AND ("pain" OR "pubalgia" OR "injury" OR "sport injury" OR "sports medicine" OR "strain" OR "tear" OR "tendinopathy" OR "rupture" OR "pathology") AND ("strength training" OR "resistance training" OR "exercise" OR "weight lifting" OR "weightlifting" OR "rehabilitation" OR "therapy" OR "treatment" OR “prevent”)

# Appendix 2

## Players Perceptions on Injury Reduction Programmes Questionnaire

# Injury Prevention Survey

Background Questions:

- Have you had an injury this season?
- Did you miss a game through injury?
- How long were you injured for?
- Do you perform any Injury Prevention Work or Prehab?
- Do you feel you would benefit from more education on Injury Prevention?

Please indicate your thoughts by placing an 'X' in the box that applies to your beliefs

1. I think we should undertake 'Prehab' in order to:

| | | | | | |
|---|---|---|---|---|---|
| a) Improve player welfare | Strongly Disagree | Disagree | Undecided | Agree | Strongly Agree |
| b) Increase team success | Strongly Disagree | Disagree | Undecided | Agree | Strongly Agree |
| c) Reduce the financial burden of injury to the region | Strongly Disagree | Disagree | Undecided | Agree | Strongly Agree |
| d) Increase my career longevity | Strongly Disagree | Disagree | Undecided | Agree | Strongly Agree |

| | | | | | |
|---|---|---|---|---|---|
| 2. At the TEAM NAME we do enough to prevent injuries with "Prehab" | Strongly Disagree | Disagree | Undecided | Agree | Strongly Agree |
| 3. I have actively engaged in Prehab this season: | Strongly Disagree | Disagree | Undecided | Agree | Strongly Agree |

4. My Prehab this season has been:

| | | | | | |
|---|---|---|---|---|---|
| a) Prescribed by the medical department | Strongly Disagree | Disagree | Undecided | Agree | Strongly Agree |
| b) Given to me by the S&C team | Strongly Disagree | Disagree | Undecided | Agree | Strongly Agree |
| c) Self-directed | Strongly Disagree | Disagree | Undecided | Agree | Strongly Agree |
| d) A combination of the above | Strongly Disagree | Disagree | Undecided | Agree | Strongly Agree |

5. I would like Prehab to be:

| | | | | | |
|---|---|---|---|---|---|
| a) Tailored specifically to me | Strongly Disagree | Disagree | Undecided | Agree | Strongly Agree |
| b) Tailored to players who have similar injuries to me | Strongly Disagree | Disagree | Undecided | Agree | Strongly Agree |
| c) Tailored to players who play in my position | Strongly Disagree | Disagree | Undecided | Agree | Strongly Agree |
| c) Same across the whole squad | Strongly Disagree | Disagree | Undecided | Agree | Strongly Agree |
| d) Integrated in to Gym sessions and warm ups | Strongly Disagree | Disagree | Undecided | Agree | Strongly Agree |
| e) As a separate session allocated on the planner | Strongly Disagree | Disagree | Undecided | Agree | Strongly Agree |

6. My Prehab/injury prevention concerns for the following season are:

7. Do you have any thoughts on how we can deliver a better injury prevention or prehab service next season?

# Appendix 3

## Ethics Forms

PRIFYSGOL CYMRU
Y Drindod Dewi Sant
UNIVERSITY OF WALES
Trinity Saint David

E1 FORM

# APPLICATION FOR ETHICAL APPROVAL - Research

# CAIS AM GYMERADWYAETH MOESEGOL - Ymchwil

| CEFNOGWYD APPROVED | | A GYFEIRIWYD REFERRED | | NIS CEFNOGWYD NOT SUPPORTED | |
|---|---|---|---|---|---|

| | |
|---|---|
| Mae'r ffurflen hon i'w defnyddio cyn cynnal gwaith ymchwil, prosiectau neu gynyrchiadau. Dylai'r ffurflen hon gael ei chwblhau gan yr ymchwilydd, yn achos myfyriwr, dylid ei gwblhau mewn ymgynghoriad â'r goruchwyliwr. Rhaid i bob ffurflen gael ei gefnogi gan Bennaeth yr Ysgol / Gyfadran. Dylai'r ffurflen gael ei chyflwyno i'r Swyddfa Ymchwil Ôl-raddedig.<br><br>**RHAID ffurflen hon gael ei chwblhau a'i gymeradwyo gan y Pwyllgor Moeseg cyn cychwyn y prosiect / ymchwil.** | This form is to be used prior to conducting research, projects or productions. This form should be completed by the researcher; in the case of a student, it should be completed in consultation with the supervisor. All forms must be supported by the Head of School/Faculty. The form should be submitted to the Postgraduate Research Office.<br><br>**This form MUST be completed and approved by the Ethics Committee prior to the commencement of the project/research.** |

## ADRAN 1 – MANYLION MYFYRIWR SECTION 1 - STUDENT DETAILS

| | | | |
|---|---|---|---|
| Enw Llawn<br>Full Name | Kate Louise Evans | | |
| Ysgol/ Cyfadran<br>School/Faculty | Wales Institute for Work-Based Learning | Rhif Myfyriwr<br>Student Number | Student 1404046 |

Teitl dangosol yr ymchwil: Indicative Title of Research:

Exploring the Efficacy of Screening and Injury Reduction Strategies in Professional Rugby Union

| Categori'r Prosiect - Ticiwch un blwch i ddynodi categori'ch prosiect | Category of Project - Please tick one box to identify your category of project | |
|---|---|---|
| **Categori A - Staff** | **Category A - Staff** | √ |
| Prosiect Ymchwil y Staff | Staff Research Project | |
| Cynhyrchiad / Cyflwyniad Ysgol | School Production / Presentation | |
| Prosiect Ehangu Mynediad | Widening Access Project | |

| Categori B – Myfyrwyr | Category B - Students | |
|---|---|---|
| Hefyd yn aelod o Staff | Also Member of Staff | x |
| Graddau Ymchwil | MPhil/PhD Research Degree Thesis | x |
| Traethawd Hir MA /Prosiect dysgu seiliedig ar waith | MA Dissertation/Work Based Learning Project | |
| Prosiect Ehangu Mynediad | Widening Access Project | |

| | | | |
|---|---|---|---|
| | | Ydw / Yes | Na / No |
| A yw hwn yn brosiect cydweithredol sy'n cynnwys ymchwilwyr o sefydliadau neu gyrff allanol? | Is this a collaborative project involving researchers from outside institutions or organisations? | | |

| | |
|---|---|
| Os ydych, rhowch y Enw llawn a manylion cyswllt y cydlynydd prosiect gan y sefydliad neu'r sefydliad: | If yes, please give the full Name and contact details of the project co-ordinator from the institution or organisation: |
| Enw llawn / Full Name | |
| Cyfeiriad / Address: | |
| Rhif ffôn (os ydy'n berthnasol)<br>Telephone (if applicable) | E-bost<br>Email: |
| Enw llawn / Full Name | |
| Cyfeiriad / Address: | |
| Rhif ffôn (os ydy'n berthnasol)<br>Telephone (if applicable) | E-bost<br>Email: |

## ADRAN 2 – GWEITHGAREDD YMCHWIL

## SECTION 2 – RESEARCH ACTIVITY

| Ydy'r prosiect yn cynnwys: | Does the project include: | Ydy / Yes | Nac ydy/No |
|---|---|---|---|
| Defnyddio holiadur neu offeryn ymchwil tebyg (atodwch drafft gopi ) | Use of questionnaire or similar research instrument (attach draft copy) | x | |
| Defnyddio prawf ysgrifenedig neu gyfrifiadurol | Use of written or computerised test | | x |

| | | | |
|---|---|---|---|
| Cyfweliad (cysylltwch gwestiynau posibl) | Interview (attach provisional questions) | | x |
| Dyddiaduron | Diaries | | x |
| Arsylwi ar gyfranogwyr a hwythau'n ymwybodol o hynny | Participant observation with their knowledge | | x |
| Arsylwi ar gyfranogwyr a hwythau ddim yn ymwybodol o hynny | Participant observation without their knowledge | | x |
| Recordio fideo neu sain | Video or audio-taping | | x |
| Mynediad i wybodaeth bersonol neu gyfrinachol heb gydsyniad penodol y cyfranogwyr | Access to personal or confidential information without the participants specific consent | x | |
| Defnyddio unrhyw gwestiynau, ysgogiadau prawf, cyflwyniad y gallai rhai cyfranogwyr eu profi fel rhywbeth sy'n achosi niwed / tramgwydd corfforol, meddyliol neu emosiynol | Administration of any questions, test stimuli, presentation that may be experienced as physically, mentally or emotionally harmful / offensive | | x |
| Cyflawni unrhyw weithredoedd allai achosi embaras neu effeithio ar hunan-barch | Performance of any acts which may cause embarrassment or affect self-esteem | | x |
| Ymchwilio i gyfranogwyr sy'n ymwneud â gweithgareddau anghyfreithlon | Investigation of participants involved in illegal activities | | x |
| Gweithdrefnau lle defnyddir twyll | Procedures that involve deception | | x |
| Gweini unrhyw sylwedd, cyfrwng neu blasebo | Administration of any substance, agent or placebo | | x |
| Dull arall o gasglu data neu fformat cyflwyno (esboniwch) | Other method of data collection or presentation format (please explain)<br><br>Hip and groin strength based testing (pre and post running based test)<br>GPS data on match and training loads<br>Injury surveillance data<br>Questionnaire on players perceptions of injury prevention | x | |

| Os NADDO i bob cwestiwn llofnodwch y dudalen gefn a'i dychwelyd i'r Swyddfa Ymchwil Ôl-raddedig<br><br>Os OES i unrhyw gwestiwn, os gwelwch yn dda llenwch y ffurflen ac yna dychwelyd i'r Swyddfa Ymchwil Ôl-raddedig | If NO to every question please sign the back page and return to the Postgraduate Research Office<br><br>If YES to any question, please complete the form and then return to the Postgraduate Research Office |
|---|---|

| ADRAN 3 – MANYLION Y PROSIECT / YMCHWIL / CYNHYRCHIAD | SECTION 3 – PROJECT / RESEARCH / PRODUCTION DETAILS |
|---|---|

| 1. | Braslun o'r prosiect | Project outline |
|---|---|---|

The aim of every multidisciplinary sports science support team is to maximise squad availability by reducing the incidence and severity of sports related injuries. Teams with greater percentage of squad availability have been shown to be more successful from a performance perspective than their low squad availability counterparts. In men's soccer, lower injury incidence was strongly correlated with team ranking position, more games won, more goals scored, greater goal difference and total league points (Eirale et al, 2013). Williams et al (2015) have recently reported clear negative associations between injury measures and team success in professional rugby union concluding that moderate reductions in injury burden may have worthwhile effects on competition outcomes for professional Rugby Union teams.

Van Mechelen's (1992) sequence of prevention is often used to reduce injury rates in professional sport. Once the teams injury incidence and severity have been established, the multidisciplinary sports science support team can identify the injuries associated with greatest time-loss and develop and implement injury reduction strategies aimed at minimising frequency/incidence and severity of these injuries in order to maximise squad availability. These injury reduction strategies are then monitored for their efficacy.

The aim of this study is to examine the efficacy of lumbo-pelvic-hip injury reduction strategies in professional rugby union and examine players perspectives on injury reduction strategies.

| 2. | Hyd y Prosiect<br><br>O / From  Summer 2015 | Duration of Project<br><br>hyd /  to Summer 2019 |
|---|---|---|

| 3. | Disgrifiad<br>Rhowch fraslun cryno o'r prosiect, heb unrhyw jargon, ac yn cynnwys beth bydd angen i'r cyfranogwyr ei wneud. Esboniwch unrhyw dermau technegol neu derminoleg sy'n benodol i'r ddisgyblaeth (Uchafswm 300 o eiriau.) | Description<br>Provide a brief outline, free from jargon, of the project including what participants will be required to do. Explain any technical terms or discipline specific terminology (Max 300 words.) |
|---|---|---|

A Public Heath Model has been proposed as a framework to promote the progression of sports medicine research towards real-world application (Van Mechelen et al 1992; Mercy et al 1993). This four-stage model progresses research in a stepwise manner from problem identification to the adoption of effective interventions. Unfortunately, most sports injury research does not result in adequate dissemination or widespread use of effective interventions. Whilst researchers have generated considerable knowledge from surveillance, risk factor identification and efficacy/effectiveness studies, this knowledge needs to be adopted by those who can use it to improve sports medicine practice. According to Hanson et al (2014) several gaps between injury prevention research and safety promotion practice hamper efforts to reduce injuries.

This study will apply the Public Health Promotion Model to reducing injuries in professional rugby union. The model comprises of four stages. Stage one will require a comprehensive injury surveillance study to establish the extent (magnitude) of the sports injury problem. Within this element, the study will identify the most costly injuries to the rugby business and players' welfare based upon incidence (frequency of injury diagnosis) and severity (number of training and playing days lost).

Stage two of the model will establish risk factors for the greatest time loss injuries sustained by the squad. These risk factors may be intrinsic (from internal forces) or extrinsic (from external forces).

Stage three will develop effective interventions aimed at reducing the incidence and severity of the targeted sports injuries. These interventions will involve a musculoskeletal and movement screen for the predisposing factors to establish the risk of such injuries to each player within the squad, and the subsequent development and implementation of injury reduction strategies including prehabilitation exercises to be administered in strength and conditioning sessions.

Stage four of the model will involve the critical evaluation of the effectiveness of the interventions based upon injury surveillance data. Once the effectiveness of the intervention has been determined it will be disseminated for widespread adoption and use.

Following a complete cycle of the sequence of prevention, players will be questioned on their perspectives so as to inform the subsequent cycle.

| | | |
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| **4.** | **Amcanion a Chyfiawnhad i'r Prosiect:**<br>Rhestrwch y nodau a diben y prosiect. Uchafswm 300 o eiriau. Defnyddio pwyntiau bwled i ganolbwyntio eich ymateb. | **Aims and Justification for the Project**:<br>List the aims and purpose of the project. Max 300 words. Use bullet points to focus your response. |

Sports related injuries are debilitating and costly from the perspective of a professional rugby business and the individual players themselves. The aim of this project is to develop an injury reduction strategy based upon the unique requirements of a Professional Regional Rugby Union Team in Wales.

**The aim of this work based project is to:-**

- Identify the greatest preventable time-loss injury in terms of injury incidence and severity
- Critically examine pre-disposing factors for these preventable sports injuries
- Develop & implement screening for the identified preventable sports injuries
- Reflect on the effectiveness of the screen
- Develop and implement an injury reduction strategy for those players deemed at risk of preventable injuries
- Critically examine the effectiveness of the injury reduction strategy on squad availability and injury surveillance data and examine players' perspectives on injury reduction strategies.

| | | |
|---|---|---|
| **5.** | **Dulliau Arfaethedig:** Rhowch fraslun o'r dulliau casglu data neu o natur yr amser mewn ymarferiadau. Dylech gynnwys technegau / dulliau penodol, tasgau y gofynnir i'r cyfranogwyr eu gwneud, amser ac ymrwymiad y cyfranogwyr a dadansoddiad o'r data. Os ydy'r prosiectau'n cynnwys gweithdrefnau / gweithgareddau nad ydynt yn dilyn arfer derbyniol a sefydlwyd eisoes, esboniwch a rhowch gyfiawnhad (hyd at 700 o eiriau). | **Proposed Methods:** Outline how the data will be collected or the nature of rehearsal time. Include specific techniques / methods, tasks participants will be asked to do, time and commitment of participants and analysis of the data. If the project includes procedures / activities different from already established acceptable practice then please explain and justify (up to 700 words). |

Submethod 1: establish the extent of the injury problem
This element of the study will be addressed by prospective injury surveillance. The researcher works as an athletic trainer/graduate sports therapist within the professional rugby union team and will collect injury incidence and severity data for one complete season alongside her clinical role. This data collection is a mandatory requirement of all professional rugby teams in Wales and is required under the Participation Agreement between the Welsh Rugby Union and the 4 professional Regional teams. For the purpose of this study, data will be extracted from the medical records of individual players and will be anonymised. The researcher will record the medical diagnosis using standard Orchard codes, the date of the injury, the date of the return to play, the number of training and playing hours lost as a result of that injury, the activity during which the injury was sustained, the players age and the players previous medical history relative to the current injury.

Submethod 2: identify risk factors
Once the greatest preventable time-loss injuries have been established from the injury surveillance data, a comprehensive literature review will examine the causative intrinsic and extrinsic factors that contribute to the likelihood of players sustaining this injury.

Submethod 3: develop interventions
As a result of the literature review, the researcher will develop a musculoskeletal and movement screen for the predisposing factors. Players will provide written consent/assent

for this testing. The researcher will then establish the risk of injury to each player (likelihood ratio). Typically, professional rugby union teams usually undertake medical screening for injury prevention in the first week of preseason (June). This musculoskeletal and movement screen will be incorporated into the standard medical screening for all players returning for the forthcoming season.
Players at risk of developing the greatest time-loss injuries will then undertake an injury reduction intervention aimed at reducing the risk factors for injury. The intervention may include self-management strategies, manual therapy, soft tissue therapy, strength and conditioning modifications and corrective exercise.

Submethod 4: evaluate their effectiveness
The effectiveness of the screening and injury reduction strategy will then be evaluated by revisiting the injury surveillance data.

Submethod 5: examine players preferences to injury reduction strategies
Using a qualitative approach, the end of season review will ask players for their thoughts on injury prevention/reduction programmes and their implementation.

| | | |
|---|---|---|
| **6.** | **Cymwysterau / Profiad Ymchwilwyr:** Rhestrwch unrhyw gymwysterau gorfodol sy'n ofynnol ar gyfer casglu data neu ar gyfer y cynhyrchiad. | **Investigators Qualifications / Experience:** List any mandatory qualifications required for the collection of data or for the production. |

Ms Kate Evans is a Graduate Sports Therapist (Society of Sports Therapists Membership number 6725, medical malpractice and professional indemnity insurance £10million). Kate holds 2 Masters of Science in Sports Therapy (University of Gloucestershire) and Sports and Exercise Science (University of Wales, Institute Cardiff) and is qualified in Immediate Care in Rugby, Pre-Hospital Admission Emergency Care (WRU, Royal College of Surgeons).

Kate has the following publications and conference presentations in the field of injury prevention and rugby injuries:

Evans, K. (2015). Methods of Assessment. In Ward, K., and Di Leva, R. (Eds). *Handbook of Sports Therapy, Injury Assessment and Rehabilitation*. Routledge.

Evans K. (2015). Preventing Hamstring and Adductor Injuries in Professional Rugby Union. Society of Sports Therapists Annual General Meeting, London

Evans, K., Hughes, J., Mathews, T., & Williams, M. (2015). Changes in adductor, abductor and hip extension strength following an intermittent running test in professional rugby union players. British Association of Sport and Exercise Sciences (BASES) Annual Conference. St George's Park, UK.

Sieniawski, J., Evans, K., Shield, A., Opar, D., Hughes, J., & Williams, M. (2015). The effect of previous hamstring injury on eccentric knee-flexor strength in professional rugby union. BASES Annual Conference. St George's Park, UK.

Evans, K., & Cady, K. (2010). A Review of Medical Provision in English Ice Hockey. International Sport Science and Sports Medicine (ISSSM) Annual Conference, Newcastle.

Evans, K., & Cady, K. (2010). Results of a Musculoskeletal Pre-Participation Screening (MPPS) programme in BUCS Super 8 Rugby League Players. ISSSM Annual Conference, Newcastle.

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| 7. | **Lledaenu Gwybodaeth / Cynulleidfa:** Rhestrwch i bwy y rhoddir neu y dangosir copi o'r canlyniadau neu adroddiad / cyflwyniad terfynol. | **Dissemination of Information / Audience:** List to whom a copy of the results or final report / presentation will be given or shown. |
|---|---|---|
| **Ms Kate Evans (Researcher)**<br>**Dr Huw Bevan (High Performance Manager, TEAM)**<br>**Dr Christine Davies & Ass Prof Dr Andy Williams (Supervisors)** | | |

| 8. | **Lleoliad y Prosiect:** Nodwch bob lleoliad lle y cesglir data neu y cynhelir ymarferiadau / cynhyrchiad. | **Location of Project:** Identify all locations where data will be collected or rehearsals/ production will take place. |
|---|---|---|
| **Caerphilly County Borough Council, Centre for Sporting Excellence (TEAM training centre)** | | |

| 9. | **Cymeradwyaeth Arall:** Oes angen cael cymeradwyaeth unrhyw sefydliad arall cyn cychwyn neu gwblhau'r prosiect? Os felly, gan bwy ac a ydy wedi'i sicrhau eisoes? | **Other Approvals:** Is there a requirement for approval from any other organisation / institution prior to starting or completing the project? If so, by whom and has it been obtained? |
|---|---|---|
| TEAM | | |

## ADRAN 4 – MANYLION CYFRANOGWYR / CYNULLEIDFA

## SECTION 4 - PARTICIPANT / AUDIENCE DETAILS

| Pwy yw'r cyfranogwyr arfaethedig? | Who are the intended participants? | Ydw / Yes | Na / No |
|---|---|---|---|
| Myfyrwyr / staff Y Drindod Dewi Sant | Students / staff of Trinity Saint David | | x |
| Oedolion (dros oed 16 ac yn gymwys i gydsynio) | Adults (over the age of 16 and competent to give consent) | x | |
| Plant a phobl ifanc dan oed | Children / legal minors | | x |
| Cleifion neu gleientiaid gweithwyr proffesiynol | Patients or clients of professionals | x | |
| Rhywun sy'n cael ei gadw yn y ddalfa neu y mae'r llys wedi cymryd cyfrifoldeb amdano | Anyone in custodial care or for whom the court has assumed responsibility | | x |

| | | | |
|---|---|---|---|
| Aelod o unrhyw sefydliad lle mae'n bosibl bod angen i unigolyn arall hefyd gydsynio. | A member of any organisation where another individual may also need to give consent. | | x |
| Eraill: Nodwch: / Others: please identify:<br><br>Senior Professional Male Rugby Union players at TEAM and Academy players over the age of 16 years at TEAM. | | | |

| **Nifer, Oed a Ffynhonnell y Cyfranogwyr**<br>Rhowch fanylion yr demograffeg y cyfranogwyr / gynulleidfa. | | **Participant / Audience Number and Age**<br>Provide details of the demographics of the participants / audience. |
|---|---|---|
| Nifer o Gyfranogwyr / yn y Gynulleidfa | Participant/ Audience number | Senior Players maximum of N= 50<br>Academy Players (above the age of 16) maximum N= 20 |
| Grŵp oedran y Cyfranogwyr/y Gynulleidfa | Participant/ Audience age group | **Senior Players 18-35 years**<br>**Academy players 16-20 years** |

| **Cyfranogwr Ffynhonnell:**<br>Sut wnaethoch chi adnabod y cyfranogwyr? Rhestru eich dulliau o recriwtio ac unrhyw feini prawf gwahardd. | **Participant Source:**<br>How did you identify the participants? List your methods of recruitment and any exclusion criteria. |
|---|---|
| The lead for this study works as Head of Rehabilitation for this professional rugby team and is responsible for injury prevention at that region. All players will be invited to take part in this study. Potential participants that have expressed interest in taking part in the study will then read the information sheet. Consent/Assent forms will be sent electronically or hardcopy in advance (minimum two weeks) of the arranged testing date. The date of musculoskeletal and movement screen testing will be arranged based on the clubs schedule with the aim to minimise disruption to their training. Testing will also be organised at least two days away from competition or a planned heavy training session. Only once signed copies of the appropriate documentation have been received will participants be allowed to take part.<br><br>Convenience sampling will be used for the initial submethod 1 & 3. All players will be asked to consent to their injury data being used for the surveillance method and all players will be screened to establish the risk of injuries.<br><br>Purposive sampling will be used for submethod 3 and 4 where players at an elevated risk of preventable sports injuries will be asked to consent to participating in the injury reduction strategy and providing their opinions on injury reduction interventions. | |

| ADRAN 5 – RISGIAU YN PROSIECT | SECTION 5 – RISKS IN PROJECT |
|---|---|
| Bydd y diffyg ateb cadarnhaol i bob un o'r cwestiynau hyn yn arwain at y gofyniad eglurhad a gallai arwain at oedi yn eich ymchwil. Dim neu Dim NID yn dderbyniol. | A lack of a positive answer to all of these questions may result in the requirement of further explanation and a delay in your research. None or Nil is not acceptable. |

| | | |
|---|---|---|
| 1. | **Risg bosibl i'r Cyfranogwyr:** Rhestrwch unrhyw risgiau posibl i gyfranogwyr (corfforol, seicolegol, cyfreithiol, cymdeithasol neu economaidd) sy'n gysylltiedig â'r prosiect. Dylech gynnwys dadansoddiad o debygolrwydd a difrifoldeb posibl unrhyw risg. | **Potential Risk to Participants:** List any potential risks to participants (physical, psychological, legal, social or economic) associated with the project. Include an analysis of the likelihood and potential severity of any risk. |
| All tests of human performance, like the movement and musculoskeletal screen in the proposed study, involve some risk, particularly of muscle soreness and soft tissue injuries such as muscle strains. While some muscle soreness may be likely for participants in this study, the risk of muscle strain injury is exceptionally low. | | |
| 1.a | **Rheoli Risg:** Rhestrwch sut y bydd unrhyw risgiau a nodwyd yn cael eu rheoli. | **Management of Risk:** List how any risks identified will be managed. |
| In the information letter participants will be made aware of the potential for some soreness (known as delayed onset of muscle soreness or DOMS) and will be advised not to be tested two days before competition or heavy training (please refer to the information sheet). At no point will invasive techniques be used.<br><br>Offsite testing will be supervised by Ms Kate Evans. Ms Evans is a qualified Graduate Sports Therapist and will be present for all testing.<br>The participants' time is another burden as a result of taking part. The time commitment will be identified on the information sheet. | | |

| | | |
|---|---|---|
| 2. | **Risgiau Posibl i'r Ymchwilydd:** Rhestrwch unrhyw risgiau posibl i'r ymchwilydd sy'n fwy na fyddai'n debyg o godi o ddydd i ddydd. | **Potential Risks to Researcher:** List any potential risks to the researcher greater than might be encountered on a daily basis. |
| None | | |
| 2.a | **Rheoli Risg:** Rhestrwch sut y bydd unrhyw risgiau a nodwyd yn cael eu rheoli. | **Management of Risk:** List how any risks identified will be managed. |
| N/A | | |

| | | |
|---|---|---|
| 3. | **Risgiau Posibl i'r Prifysgol:** | **Potential Risks to University:** |

| | | |
|---|---|---|
| | Rhestrwch unrhyw risgiau posibl i'r Brifysgol yn fwy na debygol o godi o ddydd i ddydd | List any potential risks to the University greater than might be encountered on a daily basis. |

None

| | | |
|---|---|---|
| 3.a | **Rheoli Risg:** Rhestrwch sut y bydd unrhyw risgiau a nodwyd yn cael eu rheoli. | **Management of Risk:** List how any risks identified will be managed. |

N/A

| | | |
|---|---|---|
| 4. | **Canlyniadau Niweidiol:** Rhestrwch unrhyw mesurau yr ydych wedi'u rhoi ar waith i gyfyngu ar unrhyw effeithiau andwyol neu canlyniadau'r prosiect, lle y bo'n briodol. Dylech gynnwys unrhyw brotocolau argyfwng. | **Adverse Outcomes:** List any measures you have put in place to limit any adverse effects or outcomes of the project, where appropriate. Include any emergency protocols. |

Extensive emergency action plans exist for the professional rugby team. These are written and implemented by the research lead for this project as part of her role in professional rugby union. These emergency procedures are in line with the Welsh Rugby Union minimum standards criteria and have been specifically written for the testing venue (Caerphilly County Borough Council Centre for Sporting Excellence, Ystrad Mynach).

TEAM are at low risk as their anonymity will be protected at all times. A sub-aim of this study is to reduce the financial burden of ‘sick pay’ on the rugby business by reducing the incidence and severity of preventable rugby injuries. At no point will individual players medical records or the business accounts be published in relation to this study.

Individual participants are also at low risk. Their anonymity will be protected through out. They will provide full informed consent prior to screening and their participation in injury reduction strategies. Players can withdraw consent at any time for any reason.

The lead researcher is contracted to work with the team until May 2016, when her current contract expires. Her current contract dictates that she will be informed of a failure to renew her contract within 3 months of the contract termination date. Kate has been at this professional team for 6 years.

## ADRAN 6 – MONITRO, ADBORTH A CHYFRINACHEDD

## SECTION 6 - MONITORING, FEEDBACK AND CONFIDENTIALITY

| | | |
|---|---|---|
| 1. | Monitro: Os ydych yn sylwi ar unrhyw ymddygiad sy'n groes Cod y Brifysgol Ymarfer, unrhyw ganllawiau a gyhoeddir gan y gymdeithas broffesiynol priodol neu weithred anghyfreithlon. Amlinellwch eich strategaeth adrodd. | Monitoring: Should you observe any behaviour that contravenes the University’s Code of Practice, any guidelines published by the appropriate professional association or is illegal outline the strategy of your reporting action. |

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The researcher will abide by the Codes of Practice set by the University of Wales, the Welsh Rugby Union/ TEAM and the Society of Sports Therapists.

| | | |
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| 2. | Adborth<br>Pryd a pha gefnogaeth neu adborth yn cael ei ddarparu i gyfranogwyr, os yn briodol? | Feedback<br>When and what support or feedback will be provided to participants, if appropriate? |

Individual player feedback will be given regarding their testing results from the musculoskeletal and movement screen. Where an increased injury risk is observed (e.g. significant asymmetries exist or where a weakness is evident), an injury prevention plan will be implemented by the lead researcher as part of her role in professional rugby union.

Other multidisciplinary sport science support staff (such as strength and conditioning staff, physiotherapy staff, Head of Performance) will be informed on any outcomes. As part of the medical screening, players sign a confidentiality consent form stating that:-

'In most medical settings information with the doctor or therapist remains confidential (or secret) between the patient and the clinician unless the patient agrees to the release of information. This rule does not entirely apply when a sporting team provides medical care. Any information you share with a team doctor/therapist may be shared with multidisciplinary sports science support staff and team management'

(See attached consent form)

| | | |
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| 3. | Cydsyniad Gwybodus:<br>Erbyn pa ddull yr ydych yn dogfennu'r 'caniatâd i gymryd rhan yn y prosiect' (yn cynnwys copi o'r ffurflen caniatâd os ydych yn defnyddio un). | Informed Consent:<br>By which method are you documenting the 'consent to participate in the project' (include a copy of the consent form if you are using one). |

Participants will be given a Participant Information Sheet to read prior to completing the Informed Consent form. Participants must sign the informed consent form before commencing the study. Players under the age of 18 will sign the assent form.
No players under the age of 16 will be recruited to this study.

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| 4. | Cyfyngiadau Cyfreithiol ar Gyfrinachedd:<br>Nodi unrhyw wrthdaro posibl a all godi rhwng yr angen posibl am gyfrinachedd a'r gofyniad cyfreithiol i gael mynediad at y wybodaeth, megis subpoena, rhyddid gwybodaeth ac adrodd gorfodol gan rai proffesiynau. A gynghorir y cyfranogwyr am y gwrthdaro posibl hwn? | Legal Limitations to Confidentiality:<br>Identify any potential conflicts that may arise between the potential need for confidentiality and the legal requirement to access the information, such subpoena, freedom of information and mandatory reporting by some professions. Is the participant being advised of these potential conflicts? |

Participants will provide consent to their medical information and injury history being updated over the course of the study as part of injury surveillance element. Participants will provide consent to participate in the musculoskeletal/ movement screen and injury reduction intervention. Participants are informed that they can withdraw consent at any time, for any reason, without penalty.

## ADRAN 7 – STORIO, DIOGELWCH A MYNEDIAD I DDATA / SECTION 7 - DATA ACCESS, STORAGE AND SECURITY

| | | |
|---|---|---|
| 1. | Cyfrifoldeb am Ddata a Gesglir:<br>Pwy sy'n gyfrifol am storio a diogelwch yr holl wybodaeth a gesglir? | Responsibility for Data Collected:<br>Who is responsible for the storage and security of all information collected? |
| Ms Kate Evans is the data custodian, responsible for data security. | | |

| | | |
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| 2. | Sut y bydd y data yn cael ei storio? | How will the data be stored? |
| All data collected will be anonymised, encrypted and stored (electronically and in hard copy). Kate Evans will have the code for the participant ID numbers. The location of the stored data will be in a locked cabinet in room DR106 University of Wales, Trinity Saint David, Carmarthen. | | |

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| 3. | Mynediad i Ddata:<br>Pwy fydd yn cael mynediad at y data? A oes unrhyw amodau i gael mynediad? | Data Access:<br>Who will have access to the data? Are there are any conditions to access? |
| Only Kate Evans will have access to the electronic data. | | |

| | | |
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| 4. | Cyfrinachedd / Anhysbysrwydd:<br>Rhestrwch y dulliau a fydd yn cael eu defnyddio i sicrhau cyfrinachedd ac anhysbysrwydd y cyfranogwyr. | Confidentiality / Anonymity:<br>List the methods that will be used to ensure the confidentiality and anonymity of participants. |
| All data collected will be anonymised, encrypted and stored (electronically and in hard copy) in accordance with standard research governance procedures. The participants' identity on these records will be indicated by an identification number. | | |

## ADRAN 8 - CYLLID / SECTION 8 – FUNDING

| | | Ydy / yes | Nac ydy/ No |
|---|---|---|---|
| Ydy'r prosiect yn derbyn cyllid? | Is the project being funded? | | x |
| A oes angen i'r prosiect gael ei gymeradwyo cyn cael ei ystyried gan asiantaeth gyllido? | Does the project require approval before consideration by the funding agency? | | x |
| Ffynhonnell y Cyllid | Source of Funding: Self | | |

| Adran 8 – Ychwanegwch unrhyw sylwadau pellach yr hoffech iddynt gael eu hystyried gyda'r cais hwn. | Section 8 - Please add any further comments you wish to be considered with this application. |
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| ADRAN 9 – DATGANIAD | SECTION 9 - DECLARATION |
|---|---|

| | |
|---|---|
| Rhaid i'r adran hon gael ei chwblhau gan bob parti perthnasol cyn y gellir cyflwyno' r cais i'r Pwyllgor Moeseg. | This section must be completed by all concerned parties before it can be submitted to the Ethics Committee. |
| **Datganiad**<br>**Mae'r wybodaeth a gynhwysir yma yn gywir, hyd eithaf fy ngwybodaeth a'm cred. Rwyf wedi ceisio dynodi unrhyw risgiau a phroblemau sy'n gysylltiedig â'r prosiect / ymchwil neu gynhyrchiad ac rwyf yn cydnabod f'ymrwymiadau innau a hawliau'r cyfranogwyr.** | **Declaration**<br>**The information contained herein is, to the best of my knowledge and belief, accurate. I have attempted to identify any risks and issues related to the project/research or production and acknowledge my obligations and the rights of the participants.** |

Myfyriwr / **Student** /Staff Dyddiad: / Date: 20 April 2015

| | |
|---|---|
| | Disclaimer:<br>To the best of my knowledge the above information supplied to me is correct. |

| |
|---|
| Cydlynydd y prosiect / Project co-ordinator (if appropriate)<br>NA<br>Dyddiad: /<br>Date: |
| Cyfarwyddwr Astudiaethau / Director of Studies<br>Dyddiad: /<br>Date |
| Pennaeth Ysgol / Head of School<br>Dyddiad: / Date 20 April 2015 |

| Rhaid i bob cais am ymchwil ar sail cyfweliadau gynnwys y dogfennau canlynol: | All research applications must provide the following pro-forma documents: |
| --- | --- |
| 1. Ffurflen gydsynio ddrafft<br><br>2. Taflen wybodaeth am yr ymchwil sy'n esbonio'n glir ddiben y prosiect, y deilliannau disgwyliedig a'r rheini y dangosir y canlyniadau iddynt. | 1. A draft consent form<br><br>2. An information sheet on the research that clearly explains what the project is, what the expected outcomes are and who the results will be shown to. |

**DYCHWELWCH I'R SWYDDFA YMCHWIL ÔL-RADDEDIG**

**PLEASE RETURN TO THE POSTGRADUATE RESEARCH OFFICE**

.

Cadeirydd y Pwyllgor Moeseg /Chair of the Ethics Committee Dyddiad: / Date:

# PARTICIPANT INFORMATION SHEET

## Study Title: Exploring the Efficacy of Screening and Injury Reduction Strategies in Professional Rugby Union

I would like to invite you to take part in a research study involving injury reduction screening in rugby union. We are hoping to implement injury reduction strategies to improve player welfare, maximise player availability and team success.

The study will involve participants taking part in testing to establish the risk of back, hip, groin and thigh injuries in professional rugby union players.

Before you decide whether you want to take part, it is important for you to understand what we would like you to help us do. Please take as much time as you want to read this information carefully so that you can talk about it with your coach, the medical team or the Sports Therapist who will be carrying out the project. Please don't be afraid to ask us if there is anything that you don't understand or are unsure about before deciding to take part or not.

### What is the purpose of the study?

As mentioned above, we are interested in reducing hip and groin injuries in athletes. We plan to track the strength and flexibility in and around your back, hip and groin and then review the types of injuries the team sustains. Our aim is to reduce preventable injuries, maximise player availability and help talented athletes remain injury free.

#### Why have I been invited?

We intend to work with your professional rugby team for the period of the study. As a player you have been invited to participate in the study.

#### Do I have to take part?

It is entirely your own decision to want to take part or not. If you do decide to take part in this project, we will describe the study and go through the information sheet that you will be given to keep. We will then ask you to sign a consent form to show you agree to take part. If you decide you do not want to take part then this is also okay and it will not affect you in any way.

#### What will happen to me if I take part?

We will ask you to take part in the testing of the muscles around the hip and groin, specifically the hip extensors, flexors, adductors and abductors. We may also measure your hip flexion and medial rotation range, these are non-invasive tests that will help us determine how strong and flexible you are. You will also wear a GPS tracker during training and matches to examine your work rate during training and matches. We will monitor your Hip strength and flexibility along with your GPS workload information to try to prevent hip and groin injuries. We will also ask your medical team to report in any hip, groin or hamstring injuries you may sustain during the course of the study.

Before all screening assessments you should be well rested, hydrated and have eaten appropriately (similar to preparation for a match). Please avoid consumption of caffeinated or alcoholic drinks and any hard and intensive training sessions (including competitions) two days before and after the testing.

Should you have any concerns about your fitness to take part in the study, please make sure we are aware of them so they can be discussed and your preparedness confirmed.

**What are the possible disadvantages and risks of taking part?**

Given the nature of screening, there is a low risk of DOMS. We will not schedule your medical screening testing two days before hard training sessions or competitions. As a matter of procedure, trained medical staff or first aider will be present during testing should you need attention.

**What are the possible benefits of taking part?**

We cannot promise the study will help you, but the information we get from the study will help improve the understanding of the hip and groin injury prevention in rugby athletes. You will be given feedback on your injury risk of developing the targeted injuries from the musculo-skeletal and movement screen. If you are deemed at high risk you will also be given a tailored injury-reduction strategy based upon current research evidence.

**What if there is a problem?**

If you have a concern about any aspect of this study, or need to report any adverse events that may have occurred you should ask to speak to the researchers who will do their best to answer your questions.

For information, please contact Kate Evans on 01267 676784 or by Email **Kate.Evans@UWTSD.ac.uk**.

If you remain unhappy and wish to complain formally you can do this through contacting the Faculty's Research Office.

**Will my taking part in the study be kept confidential?**

Individual participant research data, including injury surveillance information and testing results will be made anonymous (your name and any identifying features will be removed so that you cannot be recognised) and given a research code, known only to the investigator. A master list identifying participants to the research codes data will be held on a password protected computer accessed only by the researcher. Any hard paper will be stored in a locked cabinet, within locked office, accessed only by researcher. Where possible it will be transferred to electronic copies and hard copy duplicates destroyed. Electronic data will be stored on a password-protected computer known only by researcher. All data stored will be kept safe, encrypted and password protected and stored in a locked cupboard. The data will be used for analysis and reported in publications as aggregated data. Kate Evans will be the only person to have access to view identifiable data. All data will be retained for a minimum of 7 years after which it may be destroyed or deleted.

**What will happen if I don't carry on with the study?**

If at any time during testing you feel uneasy about taking part you should withdraw immediately. If you withdraw from the study all the information and data collected from you, to date, will be destroyed and removed from the study files. You do not have explain why you have decided to withdraw and it will be done without prejudice. Please also note that if during the screening/testing our qualified member of staff will be monitoring your performance and if she considers that you may be at risk of injury she will ask you to cease participation and withdraw you from the study. This is for your safety and we ask you respect this decision.

**What will happen to the results of the research study?**

On completion of the study the results will be presented to your High Performance Manager. We also plan to disseminate our findings by presenting them at selected International conferences and publishing them in academic Journals. Please note that neither you nor your team will be identified in any report, presentation or publication.

**Who is organising or sponsoring the research?**

University of Wales, Trinity Saint David is organising the research.

**Further information and contact details:**

Kate Evans
Kate.evans@uwtsd.ac.uk
01267 676784
http://www.uwtsd.ac.uk/staff/kate-evans/

Information Sheet based on: COREC/NHS National Patient Safety Agency. *Information Sheets and Consent Forms – Guidance for Researcher and Reviewers'* Version 3.0 Dec 2009.
Link to IRAS website - IRAS

**STUDY CONSENT FORM**

## Title of Project: Exploring the Efficacy of Screening and Injury Reduction Strategies in Rugby Union

Name of Researcher: **Ms Kate Evans**

Please **(INITIAL)** all boxes

1. I confirm that I have read and understand the information sheet dated (01/04/2015 version 1) for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without any consequence to myself. ☐
3. I agree to my anonymised data being used in study specific reports and subsequent articles that will appear in academic journals. ☐
4. I agree to:
    a. Having my physical characteristics measured (i.e., height, weight, mass and fat mass using bioelectrical impedance). ☐
    b. Having my injury information collected as part of the surveillance study ☐
    c. Participate in the musculo-skeletal and movement screen as part of the preseason medical screening ☐
    d. Participate in the injury reduction/ pre-habilitation programme if selected ☐
    e. Take part in a questionnaire evaluating the value of injury reduction/pre-habilitation programmes ☐
5. To the best of my knowledge I am fit to take part in this study, and agree to take part in the above study. ☐

| ____________________ | ____________________ | ____________________ |
|---|---|---|
| Name of Participant | Date | Signature |

| ____________________ | ____________________ | ____________________ |
|---|---|---|
| Name of person - taking consent. | Date | Signature |

**STUDY ASSENT FORM**

## Title of Project: Exploring the Efficacy of Screening and Injury Reduction Strategies in Rugby Union

Name of Researcher: **Ms Kate Evans**

Please **(INITIAL)** all boxes

1. I confirm that I have read and understand the information sheet dated (01/04/2015 version 1) for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without any consequence to myself. ☐
3. I agree to my anonymised data being used in study specific reports and subsequent articles that will appear in academic journals. ☐
4. I agree to:
    a. Having my physical characteristics measured (i.e., height, weight, mass and fat mass using bioelectrical impedance). ☐
    b. Having my injury information collected as part of the surveillance study ☐
    c. Participate in the musculo-skeletal and movement screen as part of the preseason medical screening ☐
    d. Participate in the injury reduction/ pre-habilitation programme if selected ☐
    e. Take part in a questionnaire evaluating the value of injury reduction/pre-habilitation programmes ☐
5. To the best of my knowledge I am fit to take part in this study, and agree to take part in the above study. ☐

| Name of Participant | Date | Signature |
|---|---|---|
| Name of person - taking consent. | Date | Signature |

**STUDY CONSENT FORM (parent or guardian)**

**Title of Project: Exploring the Efficacy of Screening and Injury Reduction Strategies in Rugby Union**

Name of Researcher: **Ms Kate Evans**

**Name of child: ____________________________________________________________**

Please **(INITIAL)** all boxes

1. I confirm that I have read and understand the information sheet dated (01/04/2015 version 1) for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

2. I understand that my child's participation is voluntary and that I am free to withdraw them at any time without giving any reason, without any consequence to them or myself. ☐

3. I agree to my child's anonymised data being used in study specific reports and subsequent articles that will appear in academic journals. ☐

4. I agree to my child:
    a) Having their physical characteristics measured (i.e., height, weight, mass and fat mass using bioelectrical impedance). ☐
    b) Having their injury information collected as part of the surveillance study ☐
    c) Participating in the musculo-skeletal and movement screen as part of the preseason medical screening ☐
    d) Participate in the injury reduction/ pre-habilitation programme if selected ☐
    e) Take part in a questionnaire evaluating the value of injury reduction/pre-habilitation programmes ☐

5. To the best of my knowledge my child is fit to take part in this study, and they agree to take part in the above study. ☐

| ____________________ | ____________________ | ____________________ |
|---|---|---|
| Name of Parent or Guardian | Date | Signature |
| ____________________ | ____________________ | ____________________ |
| Name of person - taking consent. | Date | Signature |

**From:** Postgrad Research <pgresearch@uwtsd.ac.uk>
**Date:** Thursday, 6 May 2015 at 14:22
**To:** Kate Evans <kate.evans@uwtsd.ac.uk>
**Cc:** Andy Williams <a.williams@uwtsd.ac.uk>
**Subject:** Re: EC162 EVANS Kate : Ethics Committee : Approval by Chairs Action

Dear Kate,

Thank you for the revised application which has been approved under Chair's Action as you have addressed all the conditions requested.

Please see attached a letter of confirmation as requested - a hard copy has also been sent to you in the internal mail today.

If you need anything else, please let me know.

Kind regards

**Elizabeth Cook**

***Ysgrifennydd y Pwyllgor Moeseg*** **/Secretary to Ethics Committee**


**Elizabeth Cook**
Swyddog Gweinyddol a Gwasanaethau'r Gofrestrfa / Administrative and Registry Services Officer

Ymchwil Ôl-raddedig / Postgraduate Research Office
Swyddfa Academaidd / Academic Office
Campws Caerfyrddin / Carmarthen Campus
Ffôn / Tel: 01267 676785
ebost/email: pgresearch@uwtsd.ac.uk

Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

***Trawsnewid Addysg . . . Trawsnewid Bywydau***
***Transforming Education . . . Transforming Lives***

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Green Gown Awards 2015 Winner
University League 1st award class