Risk Factors for Hip and Groin Injury in Gaelic Football

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I confirm that the word count of this thesis is less than 100,000 words

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Thesis Abstract

Introduction

Injury prevention and prediction in sports medicine is of huge importance to sports medicine professionals, coaches, and athletes as it improves performance and reduces time and money lost due to injury. Previously there has been no evidence- based prospective study in an elite population of gaelic footballers regarding the risk factors for hip and groin injury.

Aims

To investigate the etiology of hip and groin injury in sport, through prospective examination of dynamic risk factor profile and injury incidence in GAA athletes.

Methodology

The aims of this study were achieved through three strands of research: A systematic review, A nominal group and finally, a prospective study to determine how risk factor profile changes across a playing season, using a large cohort of GAA athletes and how this relates to injury incidence.

Results

This thesis encompasses a systematic review highlighting the dearth of evidence regarding risk factor analysis in this population. This is followed by the establishment of a testing protocol using consensus methods and a large, prospective study examining these proposed risk factors at two time points across a playing season. The most notable findings of the prospective study are first, that previous injury continues to be a risk factor for subsequent injury. In addition to this, clinical measures offer little value in injury prediction, however pain provocation tests and patient reported outcome measures may be useful in the monitoring of ‘at risk’ athletes.

Conclusion

This thesis suggests that continuous monitoring of a dynamic risk factor profile may be of more benefit than preseason or baseline testing. It is noted, however that it remains difficult to predict hip and groin injury at an individual level.

Abbreviations

AFL	Australian Football league
GPS	Global Positioning System
HG	Hip and Groin
TRIPP	Translating Research into sports injury Prevention Practice
WHO	World Health Organisation
ROM	Range of Movement
GAA	Gaelic Athletic Association
COSMIN	Consensus based standards for the selection of health measurement instruments
MRI	Magnetic Resonance imaging
US	Ultrasound
PRISMA	Preferred reporting items for systematic review and meta-analysis
CASP	Critical appraisal skills programme
AUD	Australian Dollars
PICO	Population, intervention, control, outcome
UEFA	Union of European Football Associations
SMD	Standardised mean difference
CI	Confidence Interval
OR	Odds Ratio
HR	Hazard Ratio
CMJ	Countermovement Jump
GroS	Groin outcome Score
BMI	Body Mass Index
STROBE	Strengthening the reporting of observational studies in epidemiology
IR	Internal Rotation
ER	External Rotation
BKFO	Bent Knee Fall Out
HHD	Hand Held Dynamometer
PRO	Patient reported outcome

1 Introduction

1.1 Background

Gaelic football is one of the most popular field sports in Ireland. It is played at intercounty and club level and prides itself on its amateur status. Gaelic football is a high intensity, high velocity contact sport characterized by intermittent short and fast movements such as sprinting, kicking and change of direction (Murphy et al., 2012). Gaelic football has similarities to Australian football (AFL) in its playing style however it is played with a round ball, whereas AFL uses an oval shaped ball. GPS data has been recently published in elite level gaelic football and reported an average match running distance covered (over 70 minutes) of 8.16km, with 1.73km covered at high speed, accelerating approximately 2.6 times per minute (Malone et al., 2016).

1.2 Epidemiology of hip and Groin injury in sport

Injuries in sport occur when mechanical energy is transferred to the body in amounts or at rates that exceed the threshold for human tissue damage (Meeuwisse et al., 2007). This can occur in both an acute and insidious manner. Hip and groin (HG) injuries often occur acutely in sport during forceful action such as kicking, sprinting and sudden change of direction (Hölmich et al., 2014). During these tasks in a gaelic football setting, energy transfer occurs at speed and could potentially lead to injury to the structures of the hip and groin. The proposed mechanism for acute adductor muscle strains involves the overstretching and eccentric force of the adductors, as they attempt to decelerate the limb during rapid abduction and external rotation or sudden change of direction (Hrysomallis, 2009). Overuse injury was defined by Di Fiori et al., (2014) in the American Medical Society for Sports Medicine position statement on overuse injury and burnout in youth sports. They state that "Overuse injuries occur due to repetitive submaximal loading of the musculoskeletal system when rest is not adequate to allow for structural adaptation to take place."

Murphy et al., (2012) conducted a four-year study of injuries in Gaelic football and reported that 9.4% of all injuries were defined as pelvic and groin, with another 3.1% defined as hip injuries. This was the first epidemiological research completed on injury

in the gaelic football population, however data on injury mechanism or specific diagnosis was not available. In 2011, A 'think tank' was completed by sports medicine professionals in the GAA in their attempts to address the issues surrounding hip and groin injury in the GAA. They reported that within academy level gaelic footballers, there was a 24% incidence of chronic groin pain, and was deemed to be the second most common problem within the sport after hamstring injury (Glasgow, 2011). A large, multi-centre UEFA study was conducted over seven soccer seasons, analysing 88 club seasons in total (Werner et al., 2009). This study reported a total of 628 hip and groin injuries (12-16% of all injuries per team per season). Injury incidence in this study was reported at 1.1/1000 playing hours (95% CI 1.0- 1.2). Incidence of injury was noted to be significantly higher in game situations (3.5/1000) versus training situations (0.6/1000). 15 % of recorded injuries were re injuries and 73% were considered overuse injuries compared to 23% of a traumatic nature.

1.3 Defining Hip and groin injury

Previously there has been a lack of consensus on diagnostic criteria and definitions of groin injuries, this therefore makes comparison between previous studies difficult (Werner et al., 2009). As the methodology of this study was being completed, the Doha agreement meeting on terminology and definitions for groin pain in athletes was completed (Weir et al., 2015). This is the first consensus meeting of its kind to discuss this topic, and results of this meeting defined five entities for hip and groin related pain. These are outlined as adductor related; iliopsoas related; inguinal related; pubic related; hip related and other causes (Table 5.1). This entity approach to defining injury to the hip and groin region which is based on history taking and clinical examination, allows for greater clarity in injury reporting and risk factor analysis in future studies. This is considered a significant step forward in improving research in HG injury.

1.4 Risk Factors for injury

Injuries are known to have a negative influence on health and sporting performance. Lower injury incidence has been strongly correlated with a teams' final league ranking and success in the UEFA champions league or Europa league (McCall et al., 2014). Previous work has been completed on this topic and several models of injury

prevention and risk factor analysis have been proposed to provide frameworks for research development in this area. These are outlined below.

1.4.1 Models of Risk factor identification and Injury prevention

Dijkstra et al., (2014) proposed a five colour health and performance risk grading system within their 'Integrated performance health management and coaching model'. This grading system proposed 5 different levels of health status for an athlete

1. Healthy: no injury/ illness
2. Asymptomatic chronic illness/ injury which is well controlled (e.g. Asthma/ previous ACL injury).
3. Symptomatic illness/ injury in full training or competition (e.g. previous ACL with mild effusion/ pain with training or loading.)
4. Symptomatic illness/ injury with modified training (e.g. recent stress fracture, unable to sustain normal load but doing modified training.)
5. Symptomatic illness/ injury – no training

It could be hypothesised that athletes with hip and groin pain, especially those for whom it is a chronic or recurring injury, spend a lot of their training time in a fluid transition from stages 2-4 of this programme, leading to a cycle of pain and disability. This is also discussed by Meeuwisse et al., (2007), who proposed a dynamic model of etiology in sport as an update to the previous work by Van Mechlen et al., (1992). In this updated model, a recursive nature of risk and causation is explored, and it is noted that exposure can alter risk factors and allow the athlete to cycle through the model repeatedly (Figure 1.1). It is also noted that sports injury is unlikely to be the consequence of one individual risk factor, but more as a consequence of the complex interactions that an athlete is subjected to, and a result of multiple risk factors and inciting events (Meeuwisse et al., 2007).

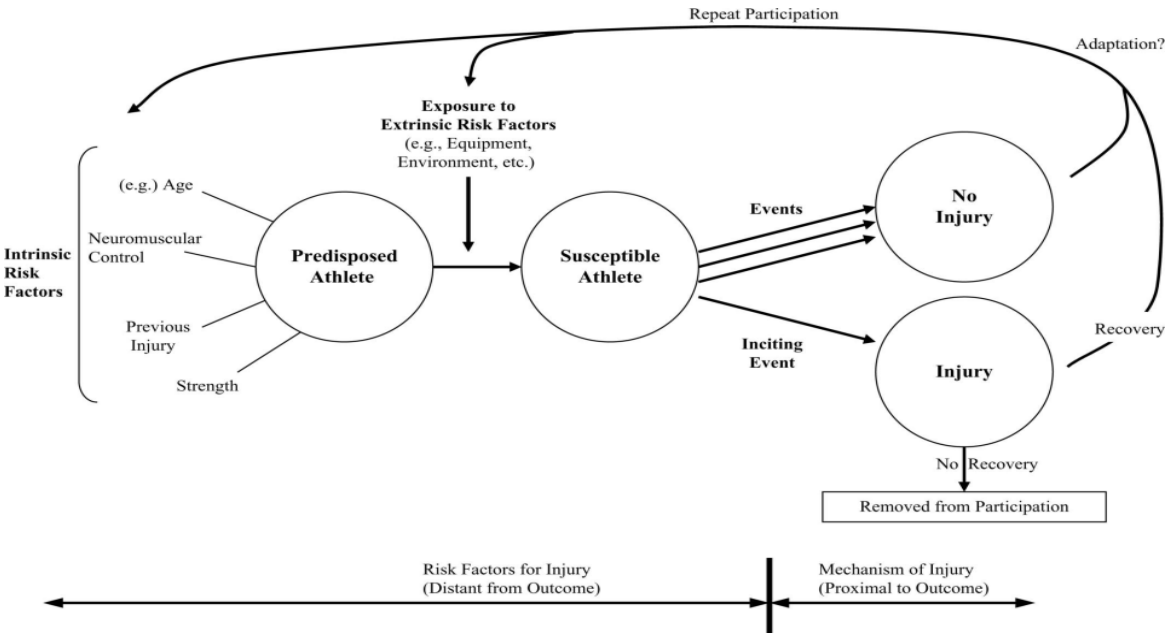


Figure 1.1: A Dynamic recursive model of etiology in sports injury (Meeuwisse et al., 2007).

Finch, (2006) proposed a framework for 'translating research into sports injury prevention practice' in the form of the TRIPP model. This model proposes six stages that are essential to build the evidence base behind injury prevention in the athletic population and is outlined in Table 1.1

TRIPP model stages	**Research process**
1	Injury surveillance
2	Establish aetiology and mechanisms of injury
3	Develop preventative measures
4	Ideal conditions/ scientific evaluation
5	Describe intervention to inform implementation strategies
6	Evaluate effectiveness of preventative measures in implementation context.

Table 1.1; TRIPP Model framework

1.5 Is 'screening' important in the sporting population?

Screening is thought of a process used to identify possible unrecognised disease or disability in individuals (Targett and Geertsema, 2013). Screening in an athlete is considered different to the monitoring of an athlete, as screening aims to gain a snapshot of the athletes' current health status and to highlight the injury/illness risk profile for these athletes. It is recommended that screening and monitoring work hand in hand to provide a fluid assessment of injury risk in athletes. The World Health Organisation (WHO) published the Wilson- Jugner Criteria for assessing a screening programme (Wilson and Jungner, 1968).

The following criteria were deemed key:

- The condition screened for should be an important health problem.
- It should be detectable at an early stage.
- There should be a treatment available for the condition that is of more benefit earlier than at a later stage.
- The test should be acceptable to the population.
- There should be an agreed policy on who to treat.
- The process should be cost effective.
- Screening tests should also be reliable, specific and sensitive.

Van Mechelen et al., (1992) states that an injury reduction strategy needs to have a step by step process. This begins with a validated injury surveillance programme, followed by the identification of risk factors, the development and introduction of preventative strategies and finally the evaluation of these strategies. As this study was being carried out in an amateur sporting population the implementation of a cost-effective methodology is essential but should include reliable, specific and sensitive testing criteria.

1.6 Statistical considerations for injury risk in sports medicine.

As noted, theoretical models of injury prevention suggest the identification of injury risk is a necessary precursor to injury prevention. Bahr, (2016) recognizes that it is the presence of internal and external risk factors that renders the athlete susceptible to injury. Furthermore, the sum of these risk factors and the interaction between them prepares the athlete for an injury to occur at any given situation. The aim of research in this area is to identify the strength of the association between the exposure of interest and injury development (Nielsen et al., 2017). Injury risk has been historically described using Risk ratios, odds ratios, and hazard ratios. Mc Call et al., (2017) argue

that this method of statistical analysis merely describes the association between the exposure and the outcome rather than predicting the outcome of interest. They suggest that statistical methods analyzing likelihood ratios in addition to positive and/or negative likelihood ratios are preferred when attempting to 'predict' an outcome. It is suggested by Mc Call et al., (2017) that explanatory power and predictive power are different quantities and the statistical methods used should reflect this. This method of analysis has never previously been explored in this population or in the analysis of hip and groin pain. Integration of these statistical methods would further benefit research in this area. This will be considered throughout this thesis.

1.7 Risk factors for hip and groin injury

To date, there has not been thorough surveillance of groin strain injury or adequate identification of risk factors to allow injury prevention strategies to be scientifically implemented and evaluated (Maffey and Emery, 2007). As injury causation is usually complex, risk factors must be clearly established before interventions can be developed and used to target 'at risk' players in the prevention of musculoskeletal injury (Steffen et al., 2008).

A systematic review was completed in 2007, which looked at the risk factors for groin strain injury in sport (Maffey and Emery, 2007). This review included eleven articles across five different sporting populations. They concluded that there were very few prospective studies completed on this topic and identified previous injury, greater abductor to adductor strength ratios, sport specificity of training and level of preseason training as individual risk factors for injury. Debate exists in the literature regarding the role of adductor length in addition to age and sport experience as risk factors, however Maffey and Emery, (2007) concluded that there is no strong evidence to support causal association for any of these risk factors and groin injury. Ryan et al., (2014) published a systematic review of the risk factors for hip and groin injuries in field based sports. This review noted that previous hip and groin injury was the most prominent risk factor (OR 2.6-7.3), followed by older age (OR 0.9) and weak adductor muscles (OR 4.28). This review concluded that future research should be completed to include a prospective study within field based sports to confirm any relationship of the risk factors identified and the consequent development of hip and groin pain. Since this

review was completed there has been a significant amount of research published so it was felt that an update on this systematic review and a meta- analysis was required. Whittaker et al., (2015), provided an updated systematic review on the same topic, with the conclusion that although cohort studies were completed in this area of research, few considered the inter-relationship between risk factors. This review also found that the non-modifiable risk factors of previous injury were prominent, but also found that higher level of play, reduced hip adductor strength and lower levels of sport specific training were also associated with a higher risk of hip or groin injury. This study recommended that the evaluation of hip and groin disability through pre-participation screening and targeted groin injury prevention programmes through RCTs which target those players deemed at greater risk of injury.

1.7.1 Modifiable and non-modifiable risk factors

Modifiable risk factors are considered those that can potentially be altered to reduce injury rates through the implementation of injury prevention strategies, whereas non-modifiable risk factors cannot be influenced in this way (e.g. age, gender etc.) (Maffey and Emery, 2007). A survey of forty -four international premier league clubs detailed the top five perceived risk factors for injury. These were listed as; previous injury; fatigue; muscle imbalance; fitness and movement efficiency (Mc Call et al., 2014). This list includes only one non-modifiable risk factor, that of previous injury. Hägglund et al., (2006) report that those with a previous history of hip or groin injury are 4.6 times more likely to sustain an injury in comparison to those with no injury history. Whittaker et al., (2015) in their systematic review, report that this statistic may result in a vicious cycle of injury and re-injury, which results in poor performance and reduced participation as well as potentially future mobility disability. Several modifiable risk factors have been proposed in relation to hip and groin injury in sport however have never been investigated in a gaelic football population. Their investigation in other populations are discussed below.

1.7.1.1 *Strength*

Isometric testing is often preferred to eccentric testing (Thorborg et al., 2011a) as it is considered less stressful on the musculoskeletal system. It has been reported that when testing asymptomatic soccer players, they showed a 14% difference in abduction when

testing the dominant side versus the non-dominant side (Thorborg et al., 2010), however no difference was noted in adduction strength profiles.
Thorborg et al., (2011c) compared hip abduction and adduction strength profiles tested isometrically in asymptomatic soccer players. A 'make' test using a hand-held dynamometer was utilised for this testing procedure. They found that the dominant side was stronger for both hip abduction and adduction isometric measures. When considering abduction/ adduction ratios between the dominant and non-dominant sides, no significant difference was reported. This study did also show that the isometric hip adduction/ abduction ratio was significantly lower in athletes who reported pain during the testing than those who reported a pain free test.
Reduced bilateral adductor strength assessed on a weekly basis using a 'squeeze' test in two junior AFL clubs was found to be related to groin pain during preseason monitoring (Crow et al., 2010). Tyler et al., (2002) suggest that in considering return to play after a lower extremity injury that achieving a hip adduction/ abduction ratio of more than 90% as well as adduction strength equal to that of the contralateral side is recommended prior to a return to sport.

1.7.1.2 *Range of Movement*

In a cohort of elite AFL players from one football club, it was reported that reduced total passive external and internal rotation was linked with chronic groin pain, This study was conducted over 2 seasons (Verrall et al., 2007). Hrysomallis, (2013) postulated that restricted hip ROM placed increased tension on the pubic region leading to bone stress. However, Maffey and Emery, (2007) reported that there was no strong evidence to support a causal association between adductor length and risk of groin injury.

1.7.1.3 *Psychological measures*

Successful sports performance requires that an athlete is mentally prepared to play as well as being physically fit and healthy (Steffen et al., 2009). Patient reported outcome measures are a method of gaining a snapshot of a person's perception of their pain and or disability. Thorborg et al., (2011b) developed a hip and groin specific outcome measure for athletes in accordance with the COSMIN guidelines and this has been deemed reliable and valid in this population.

1.7.1.4 *Workload measurement*

Using a standardised exposure of actual player hours separated between training time and game time would be very helpful in obtaining a consistent groin strain injury incidence definition in the athletic population (Maffey and Emery, 2007). Gabbett et al., (2012) found that the risk of injury was 2.7 times higher when very high velocity running exceeded 9m per session in elite rugby league players. Greater distances covered at low and medium velocity were associated with a reduced rate of injury. DiFiori et al., (2014) report that higher training volumes have consistently been shown to increase the risk of overuse injury in multiple sports and that overscheduling may lead to a high ratio of workload to recovery time.

1.7.1.5 *Radiological investigations*

Robinson et al., (2015) concluded from their prospective MRI and US study of 22 academy soccer players, that pubic bone marrow and parasymphyseal findings on MRI or inguinal canal ballooning on ultrasound were frequently found in asymptomatic athletes and did not predict injury or symptom development.

1.8 Gaps in literature

Weir, (2015) suggests that more information on prognostic factors and tools to predict who will not do well with rehabilitation are needed to inform rehabilitation and decision making processes. This coupled with the need to analyse the potential influence of previous injury as a risk factor are the first steps in injury prevention research. This type of research has not been completed in the GAA in relation to hip and groin injuries to date. From this literature review the following aims were proposed for this research project.

1.9 Overall Aim of this PhD

To investigate the etiology of hip and groin injury in sport through prospective examination of dynamic risk factor profile and injury incidence in GAA athletes.

This was completed through three strands of research:

1. A systematic review and meta- analysis.

2. A nominal group study to gain consensus on relevant risk factors in GAA population and methods of monitoring in this population.
3. A prospective study to determine how risk factor profile changes across a playing season, using a large cohort of GAA athletes and how this relates to injury incidence.

1.10 Thesis outline

This thesis is presented in research paper based format. Chapters 2 and 4-6 have been written as papers prepared for publication in sports medicine related journals.

2 Risk Factors for Hip and Groin injury in Sport: A Systematic Review and Meta-Analysis

2.1 ABSTRACT

Background: Recovery after hip and groin injury is often problematic with some athletes suffering longstanding symptoms and recurrent injury. The understanding of risk factors for injury is important in injury prevention.

Aim: To systematically review the literature relating to risk factors for hip and groin injury in athletes.

Methods: This review followed the PRISMA guidelines. Prospective studies analysing risk factors for hip and groin injury were considered for inclusion. No restrictions were made on gender or sport. Assessment of methodological quality was carried out using a modified Critical Appraisal Skills Programme (CASP) tool.

Results: Fifteen studies were included (N=7192 athletes participating across 4 sports). Study quality was moderate to high. 18 risk factors were examined; in most studies, risk factors were measured at a single time point prior to athletic exposure. One study measured risk factors periodically over a playing season. Pooled results showed that higher age [MD 1.87 yrs. (95% CI 0.93, 2.81)] and previous injury, [OR 2.32 (1.60-3.38)] were significant risk factors for hip and groin injury. Pooled results also found that injured athletes have significantly lower self-reported function [SMD 0.45 (0.22, 0.69)] and better jump height performance [MD: 1.24cm (-0.17, 2.64)] at preseason testing.

Conclusion: Athletes with higher age and previous injury are more at risk of hip and groin injury. Future studies should consider the cyclic nature of risk factors throughout a playing season, with a focus on self-reported function.

2.2 Background

Hip and groin injury is commonly reported in field sports that involve kicking, interval sprinting and rapid change of direction movements (Pizzari et al., 2008). Epidemiological studies of hip and groin injury across the various footballing codes report a prevalence of 5-28% annually (Werner et al., 2009). A recent study in GAA reported 9.7% incidence in Gaelic football and 10.4% in hurling (Murphy et al., 2012). Recovery after hip and groin injury is often problematic with many athletes suffering longstanding symptoms or recurrent injury (Thorborg and Hölmich, 2013). A recent Cochrane review (Almeida et al., 2013), found players can experience symptoms for six months after injury, with 25% failing to return to their previous level of function. This recurring cycle of injury and re-injury may lead to decreased athletic performance and/ or long term pain and disability. Hip and groin injuries can be sustained in both acute and overuse situations with acute injuries generally presenting after an overstretching incident or a contact injury. Traditionally, accurate diagnosis of hip and groin injuries was problematic. In 2007, Holmich and colleagues described a diagnostic approach based on three separate clinical entities: adductor related pain/ osteitis pubis, iliopsoas related pain and hernia/ lower abdominal pain. This criterion was recently updated to include hip joint pathology as an additional diagnostic entity; and replacement of the term osteitis pubis with pubic bone stress injury (Hölmich, 2007). Hip and groin injuries can have significant cost implications. It has been reported that groin pain was responsible for AUD 1.7 million during a single AFL season due to player unavailability alone (Pizarri et al., 2008). It was also suggested that HG injury may lead to long term economic burden due to recurrent injury as sports related hip and groin pain is often associated with joint pathology. Indeed, the prevalence of labral tears in athletes with has been reported to be as high as 55% (Groh and Herrera, 2009). Furthermore, McCarthy et al., (2001) reported that 73% of patients with fraying and tearing of the acetabular labrum also had chondral damage. This increases the risk of chondral erosion and early onset osteoarthritis in athletic populations. Indeed, Kujala et al., (1996) have reported that hospitalisation for musculoskeletal disorders in former national team athletes is higher than age matched counterparts. Such long-term implications can adversely impact on athletes' general physical activity levels after retirement from sport. It is important to develop effective

interventions to prevent hip and groin injuries in sports. To do this effectively, we must first identify important risk factors for injury. Meeuwisse and colleagues (2007) have developed an updated model describing etiology of sports injuries. This dynamic model highlights the importance of intrinsic and extrinsic risk factors for injury, and the recursive nature of risk and causation. This accounts for factors such as repeat participation in sport, recovery and adaptation over a season or career, acknowledging that an athlete can enter the injury chain any point in the model.

2.2.1 Risk factors for Hip and Groin injury.

Identifying important risk factors for injury is essential for developing effective injury prevention strategies. This approach has been used successfully for other areas of sports medicine including e.g. prevention of ACL injury (Noyes and Barber Westin, 2012) and ankle sprains (Doherty et al., 2017).

Previous studies have highlighted a number of risk factors associated with exercise related hip and groin injury, these include: muscle imbalances between the abdominal wall musculature and hip adductor muscles (Almedia 2013); deficits in hip ROM (Verrall et al., 2005), hip adductor/ adductor strength ratios (Maffey and Emery, 2007) and hip adductor weakness (Engebretsen et al., 2010). However, previous studies have not addressed the recursive nature of the risk factors and the proposed interplay between the factors (Bahr and Holme, 2003). Therefore, it is an important consideration in this piece of research, and furthermore that this is addressed in future studies.

2.3 Aims and Objectives of this Study

Aim: To systematically review the current literature relating to the risk factors for hip and groin injury in athletes.

Objectives:

- To highlight the most important modifiable risk factors and their methods of assessment
- To assess the quality of the current evidence through examination of the study's internal validity.

- To investigate the etiological framework used to inform each of the study's design.

2.4 Methods

The study protocol was developed prior to the review in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines to ensure that the data collection remained consistent and unbiased (Liberati et al., 2009).

2.4.1 Study selection

Subgroup	Selection Criteria
Population	Athletic population, no restriction on sport or level played
Exposure	Any risk factor that may increase the potential for injury
Outcomes	Hip and groin injury data of sporting origin
Study Design	Prospective studies

Table 2.1: Outline of study selection criteria

Selection criteria for the studies included in this review are outlined in Table 2.1. Only studies published in English language, and carried out in an athletic population were included in this review. No blinding of the study author, place of publication or results reported occurred. All potential intrinsic and extrinsic risk factors were included and no restriction was placed on the type of risk factor analysed (lab based, functional, biomechanical, biochemical, clinical). It was a requirement that all studies outlined their definition of an injury to allow for greater transparency in reporting, however no restriction was placed on the definitions included.

2.4.2 Types of participants

All participants were from an athletic population, no restrictions were made on gender, sport played or level of participation. All clinical entities (Hölmich, 2007) related to athletic groin pain were investigated. Hip and groin pain caused by lumbar spine, sacroiliac pain, or any visceral origin were excluded. Sub group analysis was then carried out per risk factor type.

2.4.3 Search Methods

An electronic search of Medline, Embase, Cinahl and Cochrane were carried out in November 2013. A date restriction to studies published after 1990 was applied. The PICO analysis approach to assist in the mapping of search terms was utilised (Schardt et al., 2007). Key search terms were also informed by contemporary nomenclature relating to clinical entities in hip and groin pain outlined by Holmich et al., (2007). The full list of search terms can be found in appendix A. In addition, all reference lists from obtained articles were searched for any further relevant publications. Abstracts were screened initially to ascertain if papers met the inclusion and exclusion criteria, if this was not clear from the abstract the full article was sourced and a decision was made from the analysis of the full text. The full search strategy is outlined in appendix B.

2.4.4 Outcome Measures

This review included studies that investigated the association of any potential risk factor and its influence on injury incidence and prevalence in the sporting population. Injury incidence was reported per hours of participation or exposure.

2.4.5 Data Extraction

The review author (HME) independently extracted data from the selected articles using a standard data extraction form. The data collected included the methodology of each study, the participant/ cohort characteristics, the risk factors examined, outcomes and results. (see appendix C). This extracted data and an analysis of methodological quality were summarised for each of the studies.

2.4.6 Analysis of methodological Quality

The methodological quality of the included studies was analysed by two authors (HME and CB) using a modified CASP analysis method (Lankhorst et al., 2012) and the UEFA consensus document for data collection procedures (Fuller et al., 2006).

2.4.7 Data synthesis

The majority of studies reported preseason risk factor data that was split according injury status (injured group, or un-injured group) during the observation period. For these studies, between group differences were calculated based on standardised mean

difference (SMD +95% confidence intervals CI) for risk factor data recorded on a continuous scale. Odds ratios (OR) (+95% confidence intervals) were used for dichotomous data. This analysis was carried out using RevMan software (RevMan version 5.2; Copenhagen, Denmark: The Nordic Cochrane Centre, The Cochrane Collaboration, 2012). When studies provided insufficient data to calculate SMD or OR, data was summarised qualitatively and a narrative commentary was completed. The methodology of each study was examined and those studies which utilized the same testing procedure for the clinical exam were considered for meta- analysis.

2.5 Results

A systematic search of the literature was completed in November 2013, using four databases. Manual reference scanning of all bibliographies of the included studies was also performed. A total of 3043 hits were obtained, one investigator (HME) reviewed the titles and abstracts of 1349 potentially relevant articles. (Figure 2.1). Subsequently 53 articles were retrieved in full and considered for inclusion. Fifteen articles met the inclusion criteria for this study. In cases where the lead author (HME) was undecided regarding inclusion, the second and third reviewers (CB, SMD) were consulted and a unanimous decision reached. Reasons for exclusion were; no risk factors investigated (n=7), no injury data reported (n=5), no hip/groin pain injury data reported (n=7), descriptive study (n=2); retrospective study (n=1), case control study (n=2), review only (n=6) and not in athletic population (n=3).

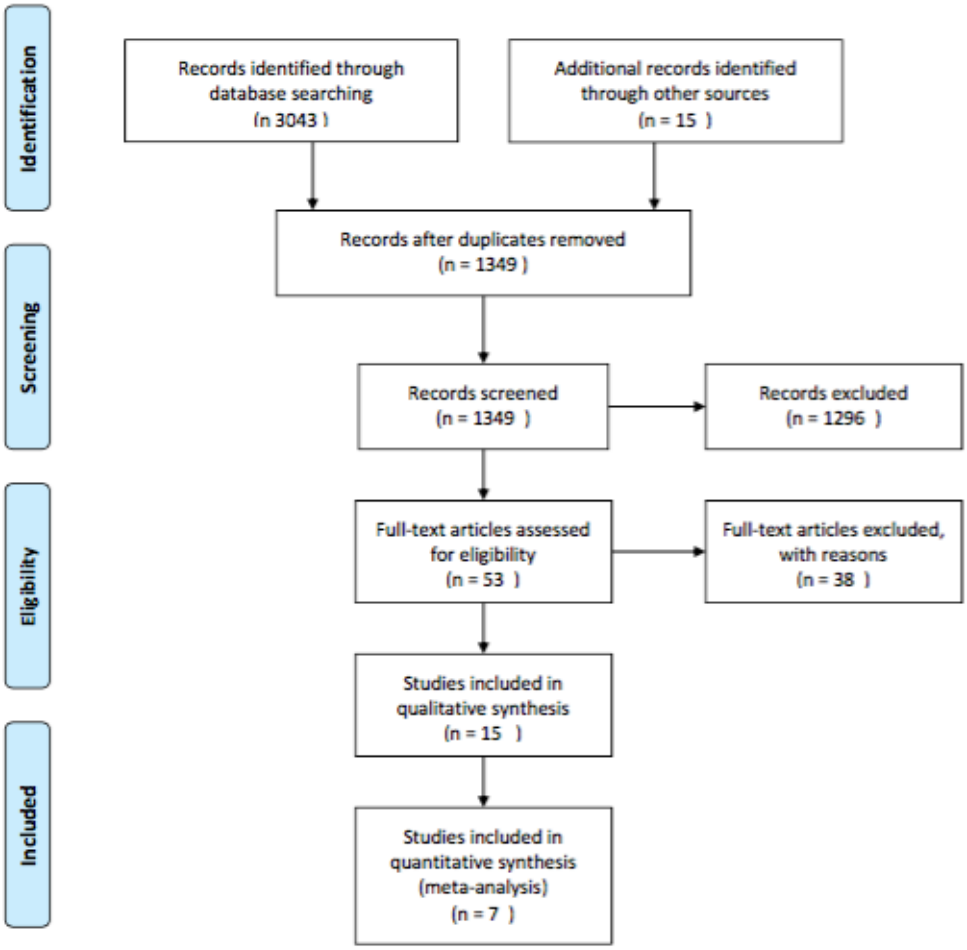


Figure 2.1; PRISMA diagram outlining search strategy and inclusion of studies.

2.5.1 Study Characteristics.

The fifteen included studies comprised a total of 7192 participants. One study did not report exact participant numbers (Orchard et al., 1998). Four different sports were represented across studies: soccer (n=7), AFL (n=3), rugby (n=2) and ice hockey (n=3). (See Appendix C for full study characteristics). Participant numbers ranged from 29-1430 with an average of 479 participants per study. Populations were both male and female and across both youth and adult athletes. In total 1046 hip or groin injuries were reported across the studies (range 4-523). Of the fifteen included studies, 13 exclusively studied male athletes, one (Schick and Meeuwisse, 2003) studied both male and female athletes and a further study (Steffen et al., 2008) included female only youth soccer players.

Sport	Number of studies	References
Soccer	**7**	(Hölmich et al., 2014); (Hägglund et al., 2013), (Arnason et al., 2004); (Engebretsen et al., 2010); (Steffen et al., 2008);(Witvrouw et al., 2003) (Hägglund et al., 2006).
AFL	**4**	(Crow et al., 2010); (Orchard et al., 1998) ; (Verrall et al., 2007); (Slavotinek et al., 2005)
Ice Hockey	**3**	(Emery and Meeuwisse, 2001); (Schick and Meeuwisse, 2003); (Tyler et al., 2001)
Rugby league	**1**	(O'Connor, 2004)

Table 2.2: Studies included by sport

2.5.2 Injury rates

Injury incidence was reported in only a third of studies. Incidence per 1000 hours ranged from 0.4- 3.2 injuries per 1000 hours. Injury prevalence in the included studies averaged at 13% (range 1-43%). In total across the 15 studies, 1046 individual hip and groin injuries were registered (Range 4-523) with one study (Orchard et al., 1998) not reporting a total number of groin injuries sustained. Injury definitions varied within the included studies. Eleven of the fifteen studies utilized a time loss definition. Two studies (Holmich et al., 2014 and Orchard et al., 1998) utilized a time loss and medical attention definition. Crow et al., (2010) defined an injury as pain on groin testing on two consecutive weeks. Verrall et al., (2007) reported chronic groin pain as a time loss injury with pain reported over 6 weeks in duration.

2.6 Methodological Quality of Included studies.

Methodological quality was assessed using a modified version of CASP criterion as previously described by Lankhorst et al., (2012) (see Appendix D). When the question was answered with a yes, a score of 1 was applied, a no yielded a zero score and any that were unclear were marked with a '?' and not counted in the final total. The quality scores ranged from 10/12 to 12/12. The mean score was 11.4/12. (Table 2.3)

All study groups were well defined and representative of their population. Only two studies had participant numbers of less than fifty. The main limitations of the studies noted were the lack of specific diagnostic criteria for hip or groin injury. Only one study provided a short follow up which was defined as less than six months (Crow et al., 2010). Six studies failed to provide risk estimates of injury, or data to allow calculation of risk estimates, which would allow for greater comparison of results and improved methodological quality.

Author & year of publication	**Criteria for Quality Score**												
	1	2	3	4	5	6	7	8	9	10	11	12	Total
Hagglund et al., (2006)	1	1	1	1	1	1	1	1	1	1	1	1	12
Arnason, (2004)	1	1	1	1	1	1	1	1	1	1	1	1	12
Engebretsen et al., (2010)	1	1	1	1	1	1	1	1	1	1	1	1	12
Wuitrouv et al., (2003)	1	1	1	1	1	1	1	1	1	0	1	1	11
Holmich et al., (2014)	1	1	1	1	1	1	1	1	1	1	1	1	12
Schick et al., (2003)	1	1	1	1	1	1	1	1	1	0	1	1	11
Steffen et al., (2008)	1	1	1	1	1	1	1	1	1	1	1	1	12
O Connor, (2004)	1	1	1	1	1	1	1	1	1	0	1	1	11
Tyler et al., (2001)	1	1	1	1	1	1	1	1	1	1	1	1	12
Haaglund et al., (2013)	1	1	1	1	1	1	1	1	1	1	1	1	12
Slavotinek et al., (2005)	1	1	1	1	1	1	1	1	1	0	1	1	11
Emery et al,, (2001)	1	1	1	1	1	1	1	1	1	1	1	1	12
Verrall et al., (2007)	1	0	1	1	1	1	1	1	1	0	1	1	10
Crow et al., (2010)	1	1	1	1	1	1	0	1	1	0	1	1	10
Orchard, (1998)	1	?	1	1	1	1	1	1	1	1	1	1	11

Table 2.3: Quality assessment of included studies

2.7 Synthesis of results.

2.7.1 Risk Factors

In total 17 different risk factors were assessed across the studies. A potential risk factor was defined as any factor that may increase the potential for injury. Statistical analysis of the studies varied, from between groups comparison using t- tests to multivariate regression models.

To facilitate the analysis, risk factors were sub-grouped into the following categories:

- Demographics and anthropometric data,
- Injury history,
- Strength,
- Flexibility,
- Training load,
- Self-reported outcome measures, pain levels.

2.7.2 Demographics and Anthropometric data,

Age was examined in eight of the included studies (Arnason et al., 2004, Engebretsen et al., 2010, Verrall et al., 2007, Orchard et al., 1998, O'Connor, 2004, Hägglund et al., 2013, Hägglund et al., 2006, Schick and Meeuwisse, 2003). Conflicting evidence is presented for age as a risk factor. Two studies found that increasing age was a significant risk factor for hip and groin injury (Arnason et al., 2004; Engebretsen et al., 2010). Orchard et al., (1998) reported a RR of 2.07 in their younger players when comparing u18 teams to adult teams in AFL indicating that the U18 age group are at higher risk than their older counterparts. (p=0.02). The other studies did not provide significant results in relation to age in isolation. Four studies (Arnason et al., 2004; Engebretsen et al., 2010; Verrall et al., 2007 and O'Connor., 2004) provided data which when pooled (n=835 participants) for the meta- analysis resulted in a SMD of -1.87 (95%CI -2.81, -0.93). One study reported increased risk of HG injury for the goalkeeping position in soccer (HR 0.58 p=0.048), no other study reported effect of playing position on injury risk. Conflicting evidence for body mass was presented, this risk factor was included for analysis in four studies however was only found to be significant by two authors (O'Connor et al., 2004; Verrall et al., 2007). Body mass was not reported as a significant result by Arnason et al., (2004) and Engebretsen et al., (2008). Percentage body fat was examined by Arnason et al., (2004) where players who sustained groin injuries were found to have significantly higher body fat percentage that their non-injured counterparts (p=0.02).

2.7.3 Injury history

Previous injury was studied in six of the included studies (Arnason et al., 2004, Hägglund et al., 2006, Engebretsen et al., 2010, Steffen et al., 2008, Emery and

Meeuwisse, 2001, Hölmich et al., 2014) and was found to be a statistically significant in each of the studies. Studies reported either HR or OR in their results. HR ranged from 1.48-2.69, with a further study (Arnason et al., 2004) reporting an OR of 7.3 Previous injury was included as a risk factor in this meta-analysis with a pooled OR of 2.32 (95%CI 1.60, 3.38) reported.

2.7.4 Strength

Subcomponents of strength and power were examined over five different studies (O'Connor, 2004, Arnason et al., 2004, Tyler et al., 2001, Engebretsen et al., 2010, Emery and Meeuwisse, 2001). The most commonly examined component was the adductor squeeze test. This was examined in four studies, three of which found a lower adductor squeeze score to be statistically significant. Tyler et al., (2001) reported that scores were 18% lower in the injured group. One study used a HHD to measure abduction: adduction strength ratios (Tyler et al., 2001), this study reported a RR of 17:1 based on a hip adduction strength measure that is less than 80% of the abduction measure. Other studies measured maximum power, countermovement jump, and standing jump but found no significant differences between those who obtained an injury and the uninjured group.

2.7.5 Flexibility

Clinical heterogeneity existed in the assessment of flexibility in the included studies. Four studies looked at adductor flexibility and a further two looked at a passive adductor stretch. The Thomas test was also administered in addition to hip internal and external rotation in another study. Overall evidence regarding flexibility measures as risk factor for hip and groin injuries is conflicting, with only Arnason et al., (2004) finding adductor flexibility significantly reduced in those who picked up an injury over the season (OR: 0.9 95% CI 0.8, 1.0 in multivariate model). Verrall et al., (2007) found a reduction in non-dominant external rotation of hip and total rotation of hip scores in those with HG injuries.

2.7.6 Training load

Six of the included studies reported injury incidence by player exposure in hours in matches/ training. Injury incidence reported higher in games by Engebretsen et al.,

(2010), who reported 1.8 injuries per 1000 match hours and 0.3 injuries per 1000 training hours. All other studies reported an overall injury incidence of between 0.4-3.2 injuries per 1000 hours of exposure. Emery and Meeuwisse, (2001) reported a decrease in risk of injury with increased levels of sport specific training in the off season. This study used a cut-off point of 18 sessions pre-season and compared injury incidence rates in those who completed the 18 sessions and those who completed less than 18 sessions. They concluded with the recommendation of at least 18 sport specific training sessions to be included in the preseason period (RR3.38).

2.7.7 Self-reported outcome measures/ pain levels.

Pain was examined using a rectus abdominus test by Engebretsen et al., (2010). This study carried out a multivariate analysis based on the players who sustained a time loss injury and reported an adjusted OR of 15.5 in those who reported a positive test. Clinically this equated to 19% of the injured group reporting a positive test versus 16% in the uninjured group. Two studies utilised a groin outcome score (Engebretsen et al., 2010, Steffen et al., 2008) however the results were not statistically significant when included in risk factor analysis (Engebretsen et al.,2010) (p=0.77) and only the symptoms subscale reached significance in the study by Steffen et al., (2008) (p=0.045).

2.8 Meta- Analysis

Due to discrepancies in methodology, it was not possible to include all studies and risk factors in a meta-analysis. Data was available to allow pooling of results for age, height, groin outcome score, hip ROM, Power (CMJ) and weight. These risk factors were included in a meta-analysis. In total seven of the 15 studies included in this review were used for the purposes of the meta- analysis. When the data regarding previous injury (n=6 studies, n=53 injuries, n=1084 total participants) was pooled, it was noted that all studies found previous injury as a significant risk factor, with the pooled OR of 2.32 (95%CI 1.60, 3.38).

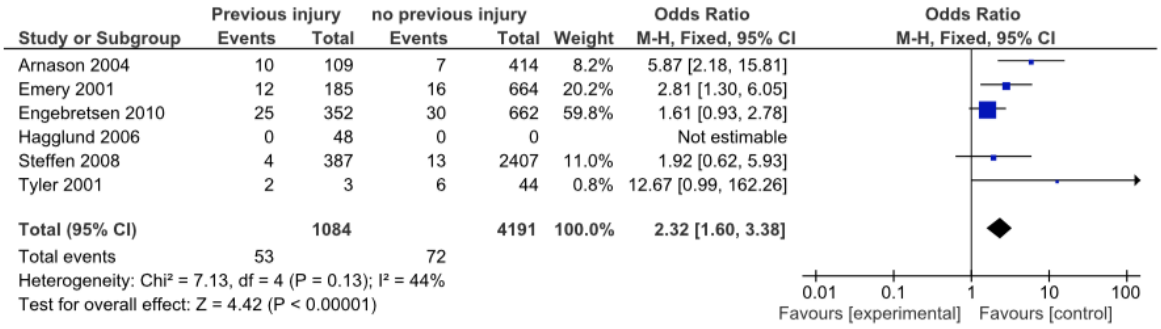


Figure 2.3: Pooled data for Previous injury as a risk factor for hip and groin injury.

Increased age was also a significant risk factor after meta-analysis. N=4 studies had data available for pooling (n=835 participants). The results show a pooled OR of 1.87 (95%CI 2.81, 0.93). Two studies utilised the groin outcome score as a measure of patient reported function (Engebretsen et al., 2010, Steffen et al., 2008), When these results were pooled a significant result was achieved [SMD 0.45 (0.22, 0.69)]. All other factors were not significant when considered for meta-analysis. (Figure 2.3).

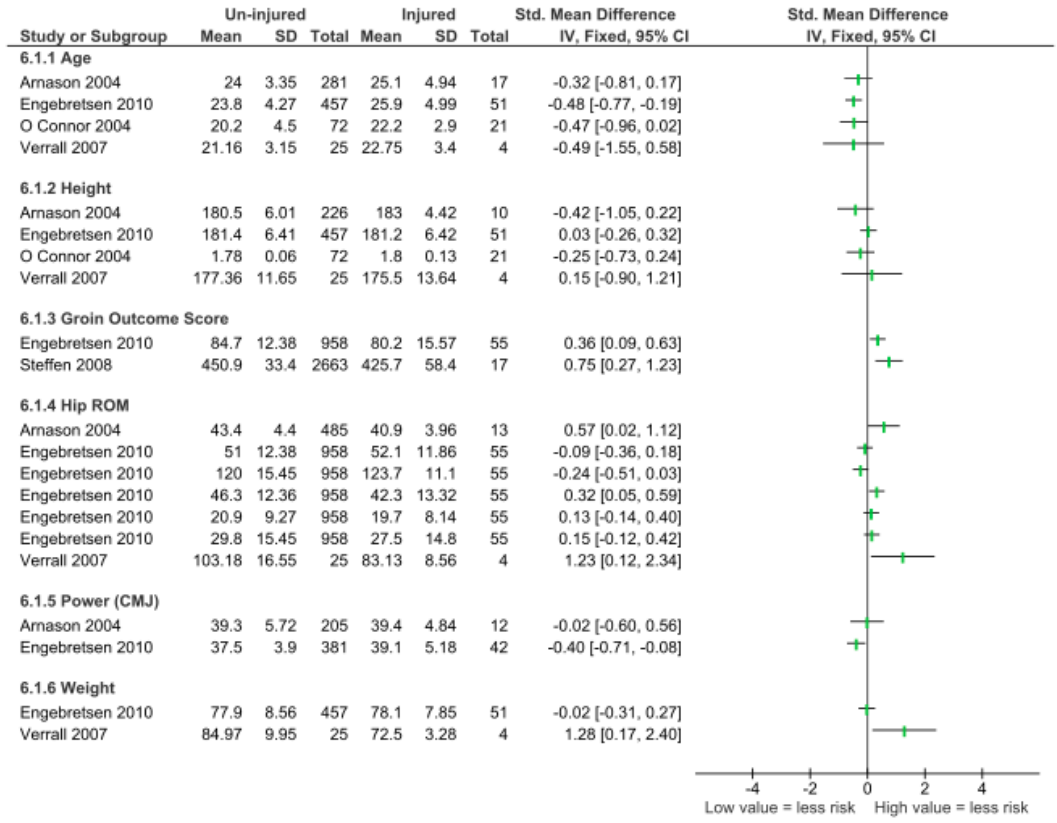


Figure 2.3; Results of meta-analysis pooled data.

2.9 Discussion

The aim of this systematic review was to evaluate the current literature surrounding risk factors for hip and groin injury in sport. A comprehensive search strategy was employed and fifteen studies were included in this systematic review. This is the first study that has included a meta-analysis of risk factors for hip and groin injury.
The secondary aims of this review were to highlight modifiable risk factors and their methods of assessment and to investigate the etiological framework used to inform the design of each of the studies. This systematic review was used to inform methodology and to develop the research questions used for this PhD. Whittaker et al., (2015) completed a systematic review on a similar topic since this review was completed. The inclusion criteria differed to this review as they included all study types, this review was limited to prospective cohort studies. Whittaker et al., (2015) concluded that the quality of studies carried has improved since the previous systematic review (Maffey and Emery, 2007). They also reported level 1 and 2 evidence to support that previous groin injury, higher level of play, reduced hip adductor strength and lower levels of sport specific training were risk factors for hip and groin injury. Due to crossovers in the studies included their results are similar to that of this review. This review adds the meta-analysis element of the systematic review to further strengthen the evidence for history of previous injury as risk factor for hip and groin injury. To date no studies have provided a rationale for the increased risk due to injury history. Generally, the studies were of good to excellent quality in their modified CASP analysis. All studies were clearly focused with the main limitations of the studies being the lack of exposure data reported and a lack of analysis of risk estimates.

The TRIPP model (Finch, 2006) suggests that research needs to move away from one team and one season studies to measuring longitudinally over many seasons and teams. This was completed by Hagglund et al., (2006, 2013) and Orchard et al., (1998). The latter of these studies only analysing age as a risk factor for injury. All other studies were completed with small cohorts or one team analysis. The analysis of multiple teams over a season or multiple seasons with multiple risk factor monitoring points is a consideration for further research.

2.9.1 Modifiable factors

Conflicting evidence was produced from this review in regards the potentially modifiable risk factors for injury. Three out of four studies that utilized an adductor strength test reported significantly lower results in injured participants with Tyler et al, (2001) reporting that scores were 18% lower in the injured group and hypothesizing that injury may be related to the eccentric loading of the adductors during deceleration in these athletes. Adductor strength could not be included in the meta-analysis due to the heterogeneity of the methodology. Abduction/ adduction strength ratio was analysed by Tyler et al., (2001) who reported a RR of 17:1 based on a hip adduction strength measure that is less than 80% of the abduction measure. This suggests that an imbalance between adductors and abductor muscle strength may increase injury risk. All other sub-constructs of strength appeared not to increase risk of hip and groin injury. The methodology employed in these studies varied considerably and standardisation of testing could help improve further research. Similar findings were reported for flexibility with differing methodologies and conflicting evidence, as such meta-analysis of these risk factors was not possible.

A decreased result in the groin outcome score was a significant result from pooled data. [SMD 0.45 (0.22, 0.69)]. Further work has been completed on the groin outcome score by Thorberg et al., (2011) where it has been adapted for a sporting population, the Hip and Groin outcome score (HAGOS) questionnaire has since been published and validated. Further research utilising the HAGOS pre- and post-injury could give useful insight into the responsiveness of a patient reported outcome measure for these athletes.

2.9.2 Non-modifiable factors

There is strong evidence from this systematic review and meta-analysis to conclude that a history of previous injury is a significant factor for subsequent injury. The meta-analysis carried out in this review reported a pooled OR of 2.32 (95% CI 1.6-3.38). Previous injury has also been reported as a risk factor for many other musculoskeletal injuries such as hamstring injuries (Freckleton et al., 2012) and ACL injuries (Volpi et al., 2016). There have been no suggestions made to date as to the rationale behind the increase in risk with a previous injury history. It would be pertinent to suggest that inadequate rehabilitation, ongoing structural damage, inadequate conditioning and

poor strength post injury may contribute to this increased risk. Age was another risk factor that when pooled data pooled from four studies revealed an OR of -1.87 (95%CI -2.81, -0.93) indicating that older players are more at risk of hip and groin injury.

2.9.3 Limitations of this review

Due to resource limitations studies in translation services were only considered for inclusion if published in the English language as translation services were not available. Due to methodology variances and lack of available data it was not possible to complete a meta-analysis with all studies and/ or including all risk factor variables.

2.10 Conclusion.

This review included fifteen high quality studies assessing a range of risk both modifiable and non-modifiable risk factors. For the first time, a meta- analysis was performed in a review of this topic. This study concluded that athletes with higher age and previous injury are more at risk of hip and groin injury. Future studies should consider the cyclic nature of risk factors throughout a playing season, with a focus on self-reported function.

3 Chapter 3: What are the key risk factors for hip and groin injury in the GAA? A nominal group study.

3.1 Introduction

The systematic review completed in chapter two concluded that there is strong consistent evidence that athletes with higher age and previous injury are at an increased risk of hip and groin injury. These known risk factors, whilst important to consider are not modifiable risk factors and are therefore not applicable when considering the development of injury prevention or monitoring programmes. From the meta- analysis, it was found that a lower patient reported outcome measure (GroS) was also a significant risk factor. From the narrative systematic review, there was some evidence to suggest that a lower score on adductor squeeze was also a potential risk factor. Numerous modifiable factors were also investigated in the included studies from the systematic review that are purported to increase the risk of hip and groin injury. These include intrinsic factors such as: lower limb strength, flexibility, range of motion, neuromuscular control and extrinsic factors such as training load, surface of play, and footwear. From the results of the completed systematic review, it has been found that there is either no evidence or weak evidence to suggest that these factors significantly increase the risk of hip and groin injury. There is currently little evidenced based information to inform the selection of risk factor variables going forward in developing a protocol for a prospective study.

In the absence of strong empirical evidence for the basis of a prospective study, it is important to determine expert consensus. It was felt that to determine the feasibility of a large prospective study, in an amateur population of athletes, that it was necessary to gain the perspective of the medical team (physiotherapists and doctors) working within intercounty gaelic football. Previous etiological research of this kind been undertaken in other sports and considering other injuries, however in the dissemination of this research often a clinical message and application of the results to that sporting population is often lost leaving the results of research often lost in translation into practice. In this study, it was deemed important that the results of a prospective study would be utilised for the development of injury prevention programmes and better

clinical understanding of risk factors for the clinicians involved. It was therefore very important that the research protocol reflected feasible monitoring procedures. It is also of note that this type of research has never been completed in the GAA population and is rarely undertaken in athletes who maintain amateur status due to limited access and resources. As such the aim of this study was to undertake a qualitative study to help identify potentially important risk factor variables associated with hip and groin injury. In addition to this, this, a secondary aim was to facilitate the formation of a template or standardised assessment to allow uniformity of the testing and reporting procedures.

3.2 Gaining Consensus

There are several methods of gaining consensus from experts in the field, including; the 'Delphi procedure', nominal group studies, focus groups and questionnaires. The nominal group technique was chosen for this study as it combines quantitative and qualitative data collection in a group setting, and avoids problems of group dynamics that can be associated with other group methods such as brainstorming, Delphi technique and focus groups (Gallagher et al., 1993). This mixed methods approach can provide depth and richness to physiotherapy research (Potter et al., 2004). It is recognised that the results of a nominal group study are rarely an end point and are to be used as an exploratory step from which the outcomes are to be further tested (Potter et al., 2004). In 2012, consensus was gained on the classification of muscle injuries using a questionnaire followed by a meeting of the world experts in the field. A nominal group technique was used during this meeting (Mueller-Wohlfahrt et al., 2013). This was a considerably larger topic than the one addressed in this study and therefore this study was conducted using a framework for gaining consensus on a smaller scale. The NGT was chosen for this study as it tends to yield more ideas than conventional unstructured type meetings which are often limited by normal group interaction and may serve to constrain freedom of speech (Cantrill et al., 1996). The NGT also allows group interaction that is absent in the Delphi procedure (Hsu and Sandford, 2007) and it facilitates data analysis to be carried out on the same day through the ranking and voting of ideas. This is a less time consuming method of gaining consensus than the Delphi method, which involves several rounds of questionnaires to gain opinion. It facilitates quick decision making and ensures that every participant can input their ideas in a safe and neutral environment. Finally, its

democratic approach equally weights the input from all group members, and the resulting ordinal data are assumed to provide a valid representation of the groups implicit views (Boehme et al., 2014). The structure and effectiveness of a nominal group approach depends on the success of collective decision making (Jones and Hunter, 1995). A disadvantage of this type of approach is the potential domination of some of the group members causing a misrepresentation of the opinions of the group. It was the job of the facilitators (HME, CB and LS) on the day to ensure that all participants can express their views as they wish without personal views dominating a discussion.

3.3 Aims

The aim of this study was to use consensus development methods to draw upon the evidence based knowledge, personal experience and general insight from a sample of expert service users (Lossius et al., 2013). The group consulted were a sample of physiotherapists and medical doctors working within intercounty gaelic football.

3.3.1 Objectives

The main objectives of this study were to:

1. Gain consensus on
    a. Important risk factors for hip and groin injury;
    b. Suitable methods of measurement;
    c. Appropriate methods for periodic monitoring of risk factors in a GAA environment.
2. To use these findings to inform the design of a prospective study in this area.

3.4 Methods

3.4.1 Study design and population

This was a mixed methods study using a sample of medical professionals (physiotherapists and medical doctors) (n=7) within inter-county men's Gaelic football. The study was undertaken over a single day at the University of Ulster (7th July, 2014). It is recommended that groups using the nominal group technique are 5-9

people in size therefore it was logical to use those with expertise in the Ulster Council area to participate.

3.4.2 Recruitment

Participants were recruited from a convenience sample predominately from Ulster GAA. All known personnel medical personnel from this area were contacted and they were selected based on their potential to provide expertise, insight and experience into factors associated with hip and groin injury. All personnel were current physiotherapists or Doctors working within intercounty GAA.

3.4.3 Group structure

The group comprised of medical staff involved in intercounty GAA football (n=7). This included physicians or physiotherapists who have worked within the GAA for a minimum of 3 years. Participants were invited to attend Ulster University on a single day, to facilitate this research. The study was completed over three hours as part of an evening seminar in July 2014. Letters of invitation (See Appendix E) were sent to all county boards in Ulster and were addressed to their medical staff. This letter provided appropriate background information in relation to the research including: its objectives and wider benefits, what information would to be collected, how information will be collected and stored, who will have access to the data, how confidentiality / anonymity will be preserved, how information will be published and disseminated, the time commitment required and what will be expected from participants on the day. At all stages of the process, participants were afforded the opportunity to ask questions about any aspect of the research. A follow up phone call was completed to aid recruitment from each county. One of the researchers (HME) was senior team physiotherapist with Monaghan GAA and in that respect, had built up a network of personal contacts with experts in this field which helped with further assisting recruitment of participants. A contact address (telephone, email) for participants who were interested in being involved in the research was also included. Informed, written consent was obtained from all participants, (see appendix F for copy of consent documentation). The right of refusal to participate in discussion and the freedom to withdraw at any stage from the research was highlighted to all attendees.

All reasonable steps were taken to maintain confidentiality and the identity of research participants. The researcher (HME) assumed the responsibility of ensuring that the social, psychological or physical well-being of research participants was not diminished through participation in the research study.

3.4.4 Facilitators

This study was facilitated by Dr. Chris Bleakley, Dr. LeAnn Sharp and Helen Mc Elroy. A nominal group approach necessitates that facilitators adhere to a strict schedule on the day of the research. It was the role of the facilitators to remain neutral in discussions, to avoid judgement and criticism between participants and to ensure that the discussion remains focused on the questions stipulated in the framework. The facilitators were responsible for the collation and analysis of the results of this study. A pilot test was carried out using a small sample (n=5) of students from the MSc Sport and Exercise Medicine course, and Chartered Physiotherapists employed within the University of Ulster. Pilot testing was used to validate the content and wording of the questions, to run through the process of group discussion and decision making and to rehearse timings.

3.4.5 Resources

This study was carried out at Ulster University, Jordanstown. Refreshments were provided to participants. The meetings were videoed to allow review of the idea generation by the facilitators. The video has been stored after the study in accordance with University data protection legislation.

3.5 Nominal Group Technique

The Nominal Group Technique (NGT) as previously discussed provides a standardised framework for brainstorming, idea generation and gaining consensus (Gallagher et al., 1993). It has been widely used and accepted as a method of generating ideas and ranking these ideas in order of importance (Cantrill et al., 1996). The suggested size for a group is 5-9 participants (Potter et al., 2004). The group structure comprises three core components: I). Introduction and problem identification. II). Generation of ideas and group discussion (III). Discussion and decision making.

3.5.1 Breakdown of NGT framework

3.5.1.1 *Introduction and problem identification:*

Participants were asked for written informed consent to participate on arrival at Ulster University. They were provided with a participant information sheet on invitation to the study and again given this information prior to commencement of the consensus meeting. Participants were then asked to complete a short questionnaire which outlined their basic demographic information (name, age, contact address), their level of (medical/ physiotherapy) experience, the team and level with which they presently work. (see Appendix F)

The PhD student (HME), introduced the topic and relevant background information, including confirmation of working definitions (risk factor, hip and groin region, injury, intrinsic, extrinsic, modifiable risk factor, screening versus monitoring) (see Appendix G). These definitions were accessible to participants throughout the evening by way of a printed handout. A standardised set of questions were then provided to each of the participants. Preliminary meetings were held with key personnel from Ulster GAA (Kevin Mc Guigan, Ulster Council Sports Scientist) and the Sports Institute of Northern Ireland (Professor Phil Glasgow, Head of Sports Medicine) to inform the questions to be addressed. The questions were based around the risk factors for injury and potential facilitators and barriers to introducing a monitoring protocol in this group of athletes.

The first set of questions addressed the factors associated with injury:

1a). What are the most important intrinsic factors associated with hip and groin injury in GAA?

1b). What are the most important extrinsic factors associated with hip and groin injury in GAA?

This process then facilitated the discussion of secondary questions which address the issues of adequate and appropriate monitoring of the risk factors highlighted from the first set of questions (Q 1a and 1b).

Question 2: What is the most appropriate and feasible way of monitoring these stated risk factors?
Method
Timing/ frequency
Who completes monitoring? (self-reported/ medical team/ coaching staff).

Hip and groin injury was considered according the definitions accepted in the clinical entity approach to diagnosing groin pain (Hölmich, 2007), (Appendix G). Each entity was discussed in turn to highlight risk factors applicable to each entity.

3.5.1.2 *Generation of ideas and group discussion*

Working individually, participants were asked to generate ideas in writing: all participants were given the opportunity to list their ideas on a flip chart and explain their rationale and opinion without interruption. All similar ideas were discussed and where appropriate grouped together, it was felt that as all group members were peers and working at a similar level in their field that issues regarding freedom of opinion should be minimised. The opportunity was given to all participants to voice any concerns to the facilitators as the study progressed. All ideas listed were discussed by the group members with new ideas allowed to be added throughout this discussion. The purpose of the discussion was to clarify, elaborate, dispute or defend any items that may have been brought up.

The group then voted on the most pertinent issues surrounding the question. This voting was carried out anonymously using turning point technologies (Solution Technologies, California). This a computer based system designed for the collation of ranked information. The participants were asked to use the keypad associated with this software to rank the constructs being considered in order from most important to least important. The technology allowed all votes to be directly transferred in to a PowerPoint presentation to show percentage rankings given by the participants. Any quantification or clarification of results was therefore immediately available and provided further discussion points within the group. Although complete anonymity in the voting process is not required to complete a nominal group study, the software used added to the robustness of the methodology and a greater assurance of honest answers. The advantage of voting anonymously via this software is that the minority

voice was also considered. The first round of voting was used to rank risk factors for hip and groin injury in order, listing the most important first. Results were collated by the facilitators to create a preliminary list of the most pertinent intrinsic and extrinsic risk factors for hip and groin injury.

3.5.1.3 *Discussion and decision making:*

The individual rankings of the risk factors were completed and collated using the turning point software which was tabulated and presented to the group for further discussion. The group then took the opportunity to discuss the result of the vote and re-analyse any issues to ensure consensus was gained and where necessary a re-vote occurred. Results from the groups were then analysed by the facilitators for recurring themes during the facilitation of the nominal group study.

3.6 Data Analysis

The outcome from this study provided a mixed-methods result. Qualitative answers were discussed and voted on to allow a quantitative ranking. The generation of ideas and the discussion/ debate of these to concluded with a consensus on the main risk factors for hip and groin injury in the GAA and their potential management. Data analysis was carried out on the day where the main themes and issues were noted and ranked in accordance with the views of the group members. Research data, both paper format and electronic, was stored in a secure location and password protected, in compliance with data protection legislation. The group work was recorded using video and audio recording to allow for revision of the discussion and write up of the results.

3.7 Results of Study

Seven medical professionals took part in the study, six physiotherapists and one medical Doctor, all physiotherapists were currently employed by senior intercounty football teams (the target audience). They had an average post qualification experience of 6 years (Range 3-12). The doctor was a multisport sports medicine specialist doctor who would regularly consult on players such as those in the target audience.

From the initial presentation and discussion on the night (led by HME) the following questions were discussed and answered using a poll based electronic voting system.

This system allowed the participants to select which factors they felt were most important and rank them in order of importance.

3.7.1 What are the most important intrinsic risk factors in relation to hip/ groin injury?

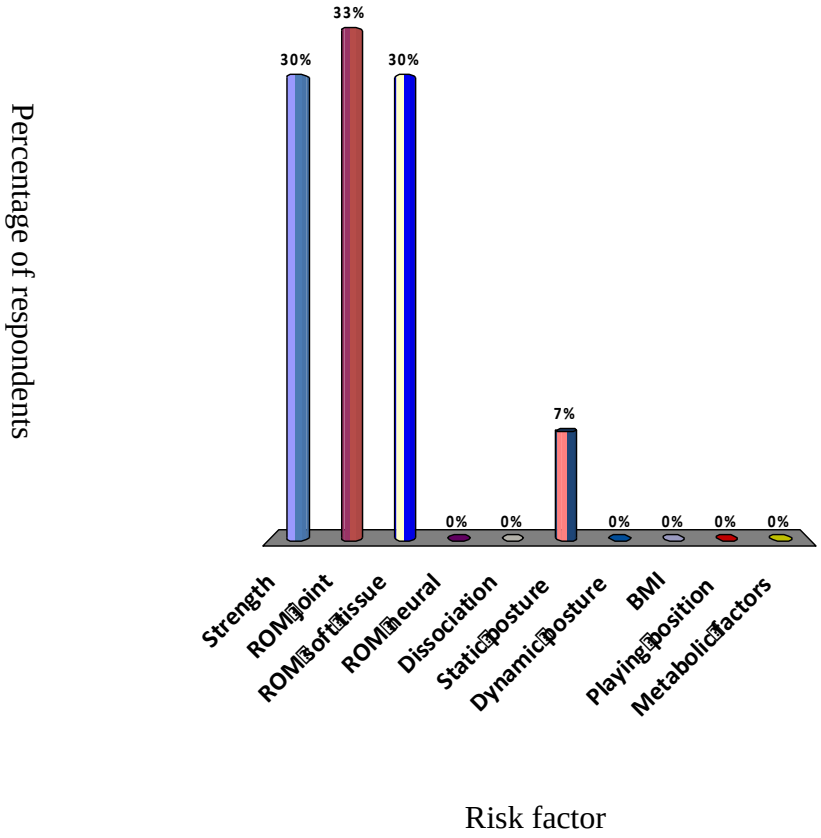


Figure 3.1: What are the most important intrinsic risk factors in relation to hip/ groin injury?

3.7.1.1 *Modifiable Intrinsic Risk Factors*

The most frequent intrinsic risk factors for a groin strain were identified as joint range of motion (33%), strength profile (30%) soft tissue range of motion (30%) and static posture (7%) (see Figure 3.1). It is notable that some factors received no votes,

namely Neural ROM, Dissociation, dynamic posture, BMI, playing position and metabolic. Each of these factors were discussed by the group in turn, in order to explore the rationale for choosing the factor.

Within this question the most frequently reported answers were dissected, therefore the next questions are specifically in relation to some of the more popular answers under the umbrella of intrinsic risk factors. The top answers in this group were in relation to the athlete's strength profile (30%) joint range of motion (33%), soft tissue range of motion (30%) and static posture (7%).

3.7.1.2 *Range of Movement*

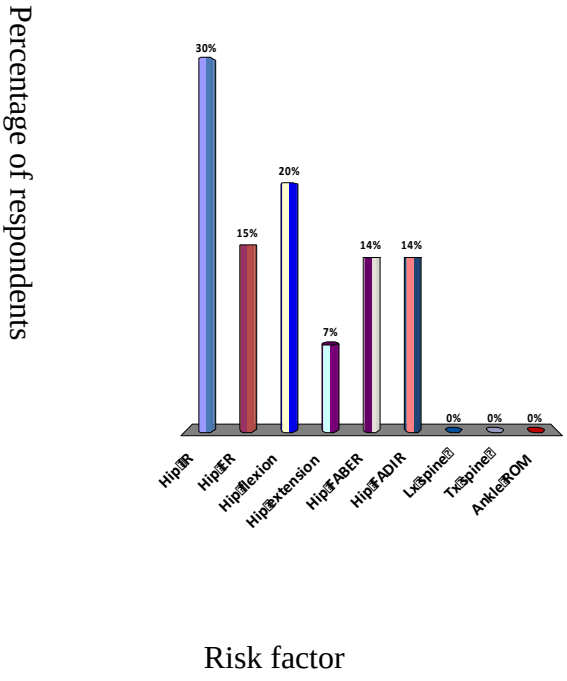


Figure 3.2: Considerations for ROM analysis

When discussing the range of movement section of the intrinsic risk factors the participants felt that several different muscles of the kinetic chain may possibly be a determinant of a specific athletes' hip and groin injury presentation. The group suggested the nine most important areas of joint range of movement that they felt contributed to injury and the ranking is illustrated in the graph above. In summary, it was felt that hip internal rotation (37%), hip flexion (20%) and hip external rotation were the most important constructs when considering the clinical assessment of

athletes in relation to hip and groin pain. The bent knee fall out test was also discussed and felt it was an important gross measure of combined ROM and should be included in the prospective study. It is not included in this graph as it is not a measure of a particular anatomic movement.

3.7.1.3 *Static Posture*

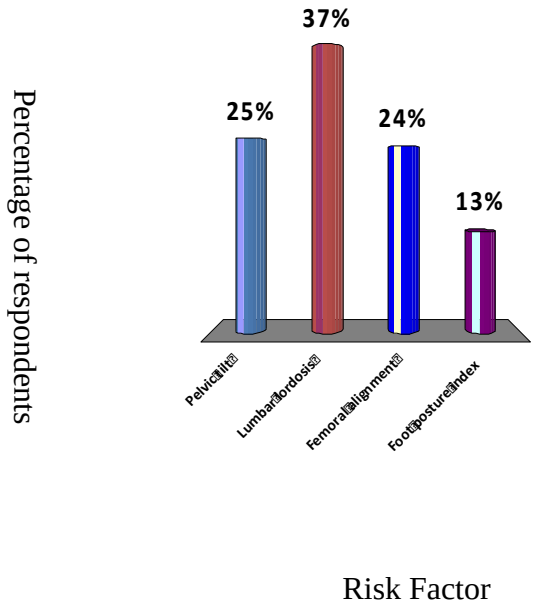


Figure 3.3: Considerations for static posture analysis

In the sub category of static posture, the participants felt that four areas were important and possibly worth considering in our assessment testing battery, pelvic tilt (25%), lumbar lordosis (37%), femoral alignment (24%) and foot posture index (13%). Methods of testing were discussed at this point and it was felt that there are few valid and reliable clinical tests for use in measuring these potential risk factors.

3.7.1.4 *Strength*

The three areas that were highlighted as potentially most important and feasible for inclusion in a testing battery were isometric hip adduction, hip extension, and a hip adduction: abduction ratio. Other sub-constructs of strength were discussed (such as isokinetic testing, power testing) however these weren't included in the voting process.

The participants felt that strength measurements should be completed in clinical not laboratory setting, using methodology that is feasible and accessible. It was recognised that although isokinetic testing may be considered ‘gold standard’ it is not widely available for this population and the dissemination of any future research results would not be applicable or useful to clinicians if using laboratory based tests. This was considered in the formulation of the testing protocol.

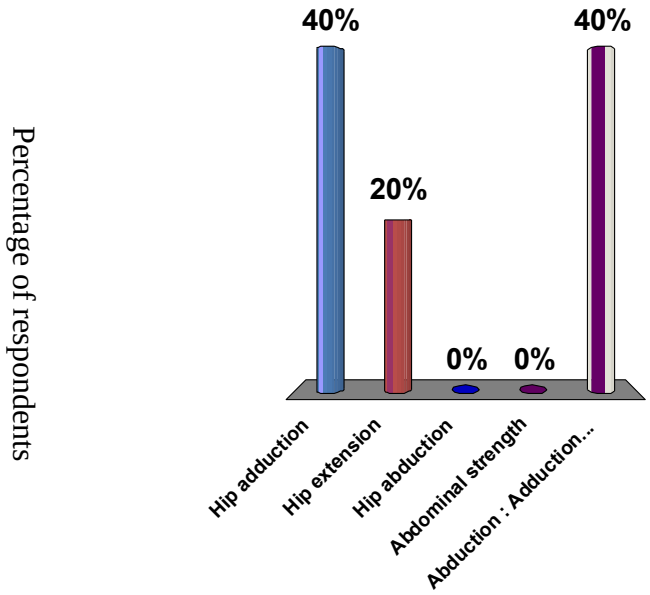


Figure 3.4: Considerations for strength analysis

3.7.2 Non-modifiable risk factors

Some non-modifiable intrinsic risk factors were also considered, most specifically past medical history, within this the three factors discussed by the group were reasonably equally weighted in the ranking process. The group felt that a past medical history that included juvenile hip pathology, lumbar spine pathology or a history of hip or groin pain were risk factors for further injury and worth considering in our analysis of demographics. It was suggested that these potential risk factors can be assessed by analysis of previous medical history questioning within a registration questionnaire.

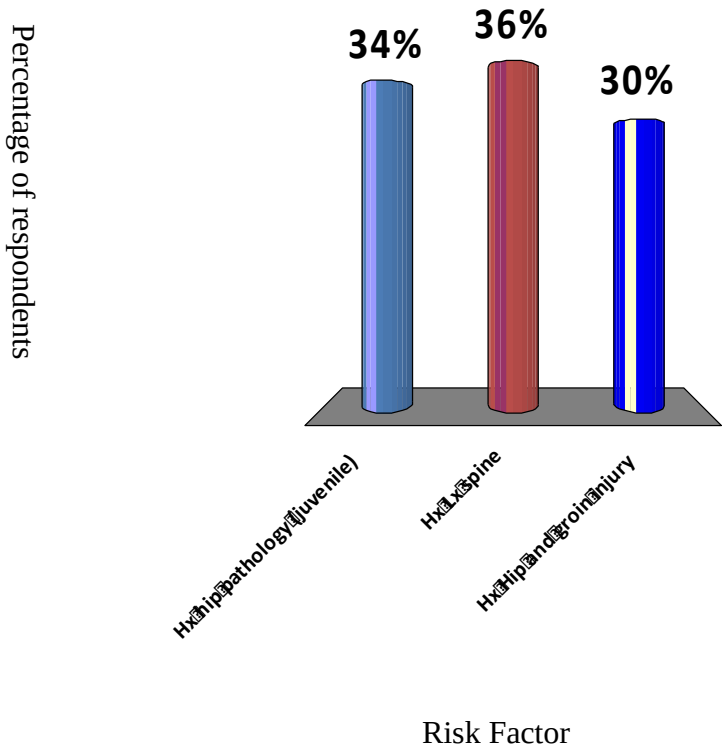


Figure 3.5: Considerations regarding previous medical history

3.7.3 What are the most important extrinsic risk factors in relation to hip and groin pain in GAA athletes?

In the discussion surrounding extrinsic risk factors the following six topics were brainstormed and discussed and then ranked; training load, surface, dual sports, athletes job, footwear and management pressures (Figure 3.6). It is not uncommon for intercounty GAA athletes to be ‘dual sports’ players. That is playing another element of gaelic games (hurling/ handball) or play another sport (usually soccer/ rugby etc.) the participants in this nominal group study felt that this was an important risk factor as well as the training surface played upon (rise of 3G pitches in Ireland due to weather conditions). The athletes’ job was considered important with regards sitting/ sedentary behaviour outside of the sport or the amount of driving undertaken. It was also noted that those athletes who complete manual labour in their daily work may be more at risk

of hip and groin pain due to the heavy loading nature of their work. Footwear was considered least important in this discussion. Management pressures were also discussed at length and considered important in this category. The main themes with regards management pressures were highlighted as; players being asked to train and play whilst not deemed fit to play by medical staff, players coming back early from injury and the fear of losing a place on a team due to being out with injury. Although the group recognised that this is not isolated to hip and groin injuries alone, they felt that as some players can adapt their game to allow them to play with pain or don't suffer from pain to after an event that it is prevalent in this injury category.

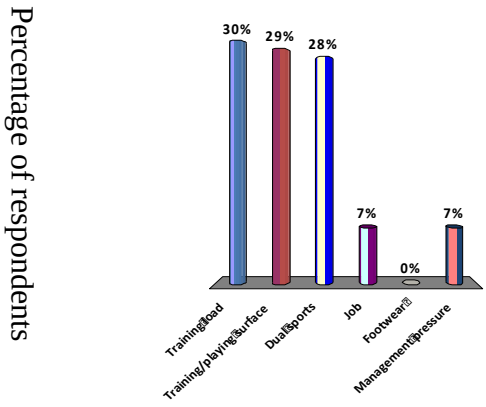


Figure 3.6: Potential extrinsic risk factors.

Training load was further explored by the group to better understand aspects that contribute to this factor, and then ranked in order of importance. The most important item in this category was the frequency of sessions completed (30%), followed by a combination of training types (gym/ pitch sessions) (21%) and a lack of adequate recovery strategies (21%). Also considered were the duration of training sessions (14%) and season clashes (14%). (Figure 3.7). This is a topical issue within the GAA at present where many intercounty gaelic footballers are exposed to several team environments at a time, and especially the younger players who may be playing for county U21's, county seniors, as well as club commitments and university teams. It was felt by the participants that this issue feeds into other extrinsic factors such as frequency of training sessions and recovery.

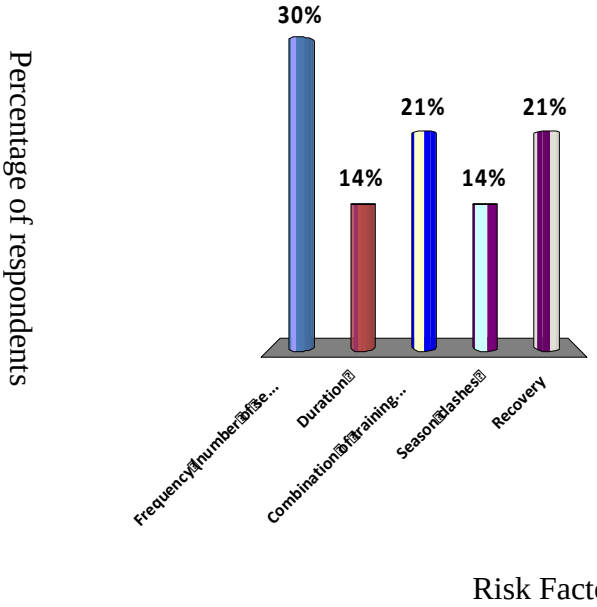


Figure 3.7: Training load considerations

3.7.4 What is the most appropriate and feasible way of monitoring these stated risk factors?

When answering Question two of this consensus development meeting, the participants participated in a verbal group discussion and felt that when considering the method of monitoring that all equipment and testing protocols used should involve inexpensive, easily accessible, yet reliable and valid methodology. The participants felt that if this research was to lead to the implementation of a monitoring or injury prevention programme that the methods should not involve laboratory testing, but all tests should be able to be easily completed 'in the field' and not involve time consuming methodology. When considering the frequency and timing of the testing for this study the participants expressed the difficulty in gaining access to the players for testing as the season progresses. Consensus was achieved as a group that a preseason and mid-season testing protocol would be feasible and manageable for players and management teams. It was also agreed that it was feasible for the physiotherapists and doctors involved to record injuries for the purposes of the study as it is a legal requirement to keep similar injury records. The group felt that it would be feasible for

the lead researcher (HME) to visit teams on the two occasions (preseason and mid-season) to carry out the clinical testing. Testing on a monthly or weekly basis was discussed at length by the group however it was felt that due to lack of funding, resources and man power for the study that this would not be practical, and would also likely disturb training plans and may lead to a hesitance to take part in the research on the behalf of the management teams.

3.8 Discussion

The results of this study yielded some interesting findings. Firstly, it was noted by the facilitators that there was a lot of enthusiasm expressed by the participants that this type of research was to be carried out in the athletic population with which they currently work as they feel there is a dearth of literature available to them on this topic. The participants identified many interesting talking points and were very engaging in their discussion and participation in the study. The main aim of this study was to facilitate the development of a standardised testing protocol for a large prospective study. It was felt that this aim was achieved and from this study the researchers could develop clearer ideas on the testing methodology and feasibility. It is felt that the nominal group technique is an adequate methodological technique for studies of this kind. The main theme that was noted during the study was that clinicians wish to be able to utilise the results of the research being carried out and if successful implement a testing/ monitoring protocol with their athletes. When discussing all possible risk factors for injury it was noted by the facilitators that the clinicians involved felt that the methodology should be easily repeatable ‘in the field’ and on a regular basis. Moreover, it should be reliable and not involve great expense to the player or expensive equipment (e.g. lab equipment such as isokinetics, optogait, etc.) which is not easily accessible. The clinicians also felt that injury reporting should be able to be completed remotely and have a standardised form to allow for all data to be included and that nothing should be omitted. The participants felt that in discussion of the risk factors that they feel that a monitoring programme would work best in day to day practice on the ‘at risk’ players. When questioned on this, they felt that the players who have a history of previous injury have a higher risk of a recurring injury and that it may be ‘time better spent’ focusing on this group rather than on the population in its entirety.

The main intrinsic risk factors discussed in this study were; strength and its sub-constructs, joint ROM, biomechanical issues and the athletes static posture as well as the demographic construct of considering the athletes' previous medical history. Several extrinsic risk factors such as lifestyle factors, training load, training surface and management pressures were also deemed important. These highlighted potential risk factors were then used to formulate the testing protocol outlined in chapter 4 of this thesis. This nominal group method of gaining consensus has been successfully used in this study and in other larger published studies (Mueller-Wohlfahrt et al., 2013). However, to the best of the authors knowledge, this method has never been used to inform the formation of a testing protocol in this manner. The main strength of this study was the immediate dissemination of the study results to the participants. This allowed for clear and meaningful discussion and a clear consensus being reached. This has been noted as a strength of the nominal group technique in other research (Harvey and Holmes, 2012) which stated that the collaborative nature of a nominal group study serves to increase the participant's ownership of the ensuing research and therefore increases the likelihood of changing clinical practice and policy.
The main limitation of this study is that the group was restricted to medical staff only. It may have been of benefit to include other service users in a different group e.g. players and coaches however it was felt that as the purpose of the study was to outline a testing protocol and feasibility of testing that it was beneficial to restrict the group to just medical professionals.

3.9 Conclusion

This nominal group study has informed a testing protocol for a large prospective study on hip and groin injury in the gaelic football population. The participants were very engaging and the emerging theme from the study was that the feasibility and success of the prospective study will be dependent on the utilisation of 'field' or clinical based tests instead of laboratory testing. This will allow greater access to participants and greater co-operation from medical staff facilitating the access to the teams. It was decided that testing should take place twice in the season, once in preseason and once in the middle of the season as this is again feasible to arrange yet will allow the dynamic recursive nature of the injury risk factor profile to be explored. The risk factors carried forward from this study to be utilised in the nominal group study were, ROM measures (IR, ER) Strength measures (adduction) and a self-reported outcome

measure. These outcome measures will be included in the prospective study and are discussed in more detail in the methodology (Chapter 4).

4 Chapter 4 Clinical and self-reported outcomes in athletes with and without a history of hip and groin injury.

4.1 Abstract

Aims: To evaluate clinical and patient reported outcomes in athletes with a history of hip and groin pain, in comparison to healthy controls. It was hypothesised that athletes with a history of pain would present with deficiencies across all outcomes when compared to controls.

Study design: Cross sectional study involving 180 intercounty Gaelic footballers

Methods: Fifty-three athletes with a history of hip and groin injury and 127 control athletes, were compared through demographics, HAGOS, hip range of motion (internal rotation, external rotation, bent knee fall out), strength (adductor squeeze) and pain provocation tests (pain during adductor squeeze Y/N), at the start of the 2014/15 playing season. Mean differences and odds ratios (95% CIs) were calculated and independent samples t-tests were performed to determine any between group differences.

Results: Athletes with a history of hip and groin injury were significantly heavier (MD ~3kgs; $p<0.05$) and had significantly lower scores across all HAGOS subscales ($p<0.001$) when compared to uninjured controls. Although we found no differences between groups in terms of age, hip range of motion and strength, athletes with a history of hip or groin pain were significantly more likely to have pain during adductor squeeze (OR 2.23 95% CI 1.16; 2.49).

Conclusion: GAA athletes with a history of hip and groin pain were significantly more likely to report subjective functional deficits and pain on adduction squeeze test at the start of a playing season.

4.2 Background

Hip and groin (HG) pain commonly occurs in sport, particularly those that involve multidirectional movements and high speed running (Orchard, 2015). This can result in significant time loss from sport and these injuries typically have high recurrence rates (Hägglund et al., 2009). A systematic review of epidemiological studies in senior football reported a higher incidence of HG injury in males compared to females and incidence rates between 0.2 to 2.1 per 1000 participating hours (Waldén et al., 2015). Gaelic Football is a field based sport predominately played in Ireland but is gaining popularity worldwide. It is an amateur sport played over 70 minutes in teams of 15 players. It is an intermittent high intensity contact sport that has similarities to Australian Football (AFL) (McIntyre, 2005). Its high speed and multidirectional nature mean that players may be at significant risk of HG injury. To our knowledge there has only been one injury surveillance undertaken in intercounty Gaelic football; this involved 4 years of data collection with the pelvis, hip and groin regions constituting approx. 13% of all injuries (Murphy et al., 2012).

Minimising the risk of injury in sports is a key priority. Meeuwisse et al., (2007) have developed a model describing the etiology of sports injuries. The model's central principle is that athletes may be predisposed to injury due to the presence of intrinsic and extrinsic risk factors that can change over time and can interact with each other. Previous injury is a known risk factor for subsequent injury in hip and groin injuries (Whittaker et al., 2015, Ryan et al., 2014, Maffey and Emery, 2007) however the explanatory path model is unclear from previous literature. One possibility is that following a HG injury, many athletes return to training and/or competition prior full recovery. It is therefore possible that any unresolved HG pain or symptoms would present at pre-participation / preseason examination; however, this has not yet been examined in a GAA population.

4.3 Aims

The aim of this study was to examine clinical and self-reported outcomes in a cohort of GAA athletes with a history of HG pain, making comparisons to healthy controls (with

no history of HG pain). It was hypothesised that at preseason testing, athletes with previous history of HG pain will have lower self-reported scores on HAGOS testing and display clinical deficits in ROM and strength in comparison to healthy controls.

4.4 Methodology

This was a cross sectional study. STROBE guidelines (Von Elm et al, 2007) were utilised to inform the study methods. At the start of the study a convenience sample of seven senior GAA teams from across Ireland were recruited. All teams in Ulster and surrounding areas were contacted via letter and follow up phone calls. The study was approved by Ulster University Ethics committee and participants from each team provided written informed consent. A total of 180 adult male (aged 18-34 years) inter-county Gaelic footballers were recruited at the start of the 2014/15 playing season, with all testing taking place in the preseason period (October/ November 2014). To be included, participants had to be male, aged over 18 years of age and currently playing Senior or U21 football at inter-county level. Participants were excluded if they were not currently available for team selection.

4.5 Outcome Measures

All players completed a standardised questionnaire to determine demographics, age, current team and previous medical history. The Doha Consensus provides minimum reporting standards for clinical research on groin pain (Delahunt et al., 2015). Although the development of the methodology for current study preceded the development of the Doha consensus statement, our study methodology fulfils most of desired criteria. Based on a standardised definition of injury from Fuller et al., (2006) participants were categorised into either cases with history of HG injury, or controls with no history of HG injury. When participants reported a history of HG injury history, we used the information within the questionnaire and liaised with the corresponding medical teams, to retrospectively categorise these into clinical entities as outlined by Weir et al., (2015).

Participants then completed the Copenhagen Hip and Groin Outcome Score (HAGOS) questionnaire (appendix K). This is a validated (Thorborg et al., 2011b) hip and groin specific questionnaire that includes 37 (Likert scale) questions in relation to symptoms, stiffness, pain, physical function, daily living, sport and recreational activities and

quality of life. The questionnaire evaluates hip and groin disability status from 0-100, where 100 indicates no disability and 0 indicates severe hip and groin problems (Thorborg et al., 2014).

Finally, a series of clinical tests were undertaken based on: hip ROM; strength; and pain provocation. All tests were completed by a single investigator. Measurements of hip internal rotation (IR), hip external rotation (ER) and bent knee fall out (BKFO) followed a standardised procedure, reported to have excellent intra-rater reliability (Malliaras et al., 2009). Hip ER and IR were measured using a bubble inclinometer, placed 10cm proximal to the lateral malleolus. For ER, participants were positioned in supine with hips in neutral alignment and the knee flexed to 90 degrees over the end of a plinth. For hip IR, participants were positioned in prone with knees flexed to 90 degrees. For both tests, the investigator passively moved the hip, continuing until the end of motion was felt or there was excess movement at the pelvis. No over pressure was applied to these tests and the inclinometer measured the angle between the lateral aspect of the limb and vertical and was recorded to the nearest degree.

A BKFO test was used to assess hip adductor flexibility. The participant was positioned with hips flexed to 45 degrees and knees flexed to 90 degrees, both verified using goniometry. Feet were placed together and the participants were instructed to allow the knees to fall outwards to the limit of motion. Overpressure was applied to ensure that the relaxed limit of motion was reached. The distance between the head of the fibula and the surface of the plinth in which they were lying was measured using a tape measure (recorded to the nearest 0.5cm). This procedure was previously outlined by Nevin and Delahunt, (2014). The final outcome recorded was the adductor squeeze test. Participants were positioned in crook lying with hips at 45 degrees flexion, knees at 90 degrees flexion. (again verified by goniometer). A sphygomometer was inflated to 40mmHg and placed at the most prominent point of the participants' medial femoral condyles. The participant was then instructed to squeeze as hard as possible on the inflated cuff and the highest pressure displayed on the dial was recorded. This test was repeated 4 times with a 2-minute rest period between testing. Participants were also asked to indicate if they felt pain during this test. All clinical measures were previously described by Nevin and Delahunt, (2014).

4.6 Statistical Analysis

For the purpose of statistical analysis, participants were sub-grouped into cases (n=53) and controls (n=127) based to their injury history. For all analyses, descriptive statistics were generated with scale variables presented as mean (±SD) and categorical variables presented as counts (%). For each dependent variable, bar charts and pie charts were initially examined to compare differences across sub-groups (history of injury vs no history of injury). Independent T-tests or chi- squared tests were used to determine statistical differences ($p<0.05$) for scale and categorical outcomes respectively.

4.7 Results

4.7.1 Demographics

Baseline results were available for all 180 participants, with no missing data reported. The mean age of participants was 23.7 years (SD 3.43). 28% (53/180) had a history of HG injury, the majority of which were adductor related (n=16/53), with n=9 reporting multiple clinical entities (Figure 1). There was no difference in the age of the participants based on their previous injury status (p=0.68). However, those with a history of previous injury were significantly heavier (84.1± 6.2kg) than their non-injured counterparts (80.6±6.7kg; p=0.016).

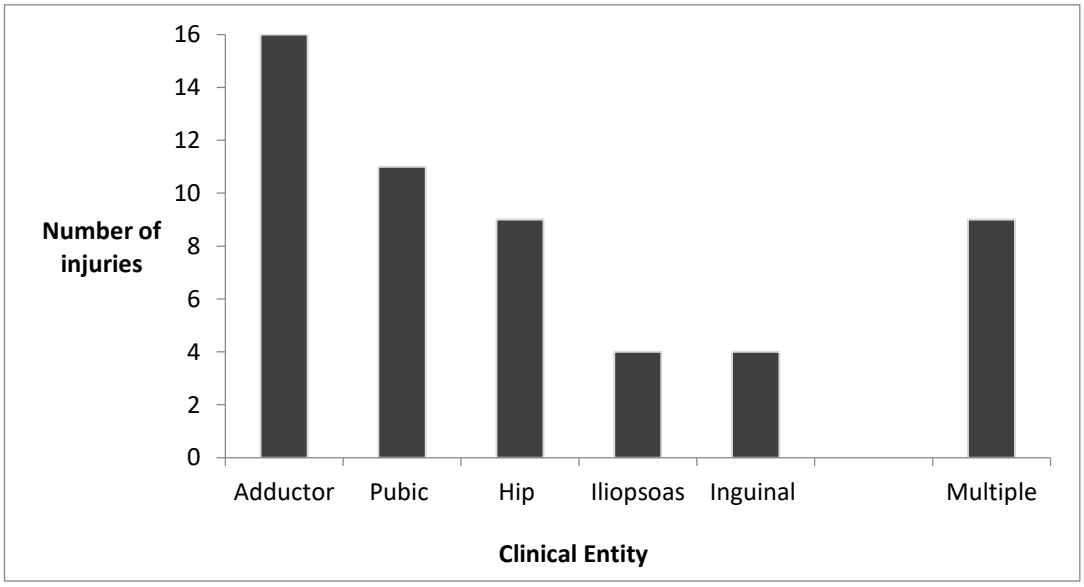


Figure 4.1. Breakdown of Previous Injury by Clinical Entity (N=53)

4.7.2 HAGOS

Table 4.2 shows mean scores (±SD) for each component of HAGOS, sub-grouped by injury history. Participants with previous HG injury had significantly lower scores on all HAGOS subscales ($p < 0.001$)

	Previous Injury	
	Yes (n=53)	No (n=127)
Symptoms	76.9(11.8)	87.6 (10.4)***
Pain	75.3(19.9)	90.4 (13.9)***
ADL	86.3 (15.9)	94.3 (10.7)***
Sport/ Recreation	73.0 (19.9)	89.7 (13.4)***
PA	74.0 (27.4)	90.4 (15.6)***
QOL	61.92 (22.3)	88.8 (14.0)***

All Values are Mean (±SD)

*** $p<0.001$

Table 4.2: HAGOS components, grouped by injury history.

4.7.3 Clinical testing

Although there were trends that participants with a history of injury had reduced hip ROM, there were no statistically significant differences between groups for hip IR, ER and BKFO scores (Table 3). Similarly, no differences in strength were found between the previously injured (171.1 SD 28.4) and uninjured (169.2 SD 27.2) ($p=0.68$). However, participants with a previous history of hip and groin pain were significantly more likely to have pain during adductor squeeze (OR 2.23 95% CI 1.16; 2.49) when compared to participants with no history of HG injury.

		Previous Injury	
		Yes (n=53)	No (n=127)
Dominant	IR (°)	21.1 (6.5)	22.0 (5.5) ns
	ER (°)	25.8 (5.5)	26.2 (5.2) ns
	BKFO (cm)	17.7 (5.0)	18.7 (5.5) ns
Non-Dominant	IR (°)	21.0 (6.4)	21.6 (5.5) ns
	ER (°)	26.2 (6.3)	25.3 (5.3) ns
	BKFO (cm)	17.9 (5.7)	18.7 (5.4) ns

All values are mean (±SD) ns, non-significant

Table 4.3. Hip ROM grouped by injury history

4.8 Discussion

To the best of the authors knowledge this is the first time that clinical and patient-reported outcomes have been analysed in a large cohort of GAA athletes with a history of HG injury, with additional comparisons made to control athletes with no history of HG injury. 180 participants were recruited from seven senior county teams across Ireland. Participants' mean age and weight were 23.7 years and 82.2 kg respectively, which aligns with earlier demographic data reported in Gaelic Football (Nevin and Delahunt, 2014, McIntyre, 2005). All testing was undertaken in the preseason period prior to the 2014/15 playing season. Interestingly, participants with a history of HG injury were approximately 4kg heavier than controls, a difference that was statistically significant. Nevin and Delahunt, (2014) also reported that injured gaelic football players were significantly heavier (80.3± 9.7 kg) than their uninjured counterparts (72.3± 10.3kg), and in a prospective study involving AFL athletes, Orchard, (2001) found that athletes with a higher BMI were at greater risk of hamstring and calf injury.

Similar patterns have been reported in other contact sports including rugby (Archbold et al., 2015) and American football (Tyler et al., 2006). The cross-sectional nature of the current study means that it is difficult to ascertain if heavier weight is a primary risk factor for HG injury, or develops during the convalescence period post injury.

HAGOS is the most common PRO used in the assessment of HG function and normative values for healthy soccer players are now available (Thorborg et al., 2014). Interestingly, it was found that HAGOS scores in this population were generally lower than the suggested normative values. This was evident within the quality of life subscale where the mean value of 62 fell just outside the suggested reference range of 64-80. Further research is required, but it is possible that normative values in gaelic football players are lower than soccer players.

Mosler et al., (2015) suggest that PROs, such as HAGOS, can accurately distinguish players with and without groin pain. In a study of 695 sub elite male soccer players (Thorborg et al., 2015) it was reported that players with previous pain or injury, had lower scores across all subcontracts of HAGOS, compared to uninjured controls. Similarly, in this study it was found that athletes with a history of HG injury scored consistently lower than controls across each of the HAGOS subscales. Further work by Delahunt et al., (2016) suggests that the function, sport and recreation subscales have a strong predictive validity for HG injury, based on cut point of 87.5 (positive likelihood ratio of 2.56). Interestingly additional exploratory analyses using dichotomized scores, only 33.1% of participants with a history of injury reached the 87.5 threshold suggested as a cut off for the sport, function and recreation subscale. In contrast, 71% of the control reached this threshold, perhaps providing additional support for the clinical utility of the cut points suggested by Delahunt et al.,(2016).

All participants undertook the adductor squeeze test during preseason period. This test has been used extensively in the literature to assess adductor strength in athletic populations. Nevin and Delahunt, (2014) recorded significantly lower adduction strength scores in a cohort of gaelic footballers with groin pain (202.88mmHg), when compared to uninjured controls (269.33mmHg). Although this study noted that athletes with a history of injury were significantly more likely to have pain on squeeze testing, there was no between group differences in strength. Of note the average adduction squeeze scores in the current study were lower than those reported in other athletic populations (Hodgson et al., 2015). This could relate to differences in testing procedure. Others have used 10mmHg as the standard pre-inflation value prior to

testing. As this could not be replicated with the brand of sphygomometer used in the current study, it was necessary to standardise pre-inflation to 40mmHg. It is not clear how this change affects test accuracy, but certainly highlights a need for standardisation of test procedures in this area.

Presence of pain reported during the squeeze tests was also of interest in this study. There is evidence from a recent systematic review (Mosler et al., 2015), that patients with ongoing HG pain are significantly more likely to report pain on a squeeze test (OR 4.31, 95% CI 1.86 to10). The cases in the current study had a history of HG pain, but nonetheless, they were still more than twice as likely (OR 2.23 95% CI 1.16; 2.49) to report pain on a squeeze in comparison to controls with no history of HG pain. As athletes with a history of HG injury also had significantly lower self-reported function, it is clear that a large percentage of athletes in our cohort do not wait until full resolution of their HG symptoms before returning to play. As testing was undertaken during preseason, it is evident that these athletes were entering a competitive training cycle at increased risk of exacerbating their symptoms and potentially re-injury. Similar patterns have been reported by Tak et al., (2016) where a cohort of soccer players returned to play, prior to full resolution of their HG symptoms.

No significant differences in hip ROM were noted based on previous injury status. Previous reviews have found conflicting evidence linking ROM and hip and groin injury (Whittaker et al., 2015). Pooled results from 3 high quality studies found that hip pain was associated with small limitations in hip ROM (3.7 degrees in IR) and BKFO (3.6cm) compared to controls (Mosler et al., 2015). In contrast, Tak et al., (2016) found no differences in hip ROM (combined IR and ER) and BKFO between painful and pain free hips.

4.9 Limitations and future research

This is one of the largest studies examining hip and groin injury within the GAA. There are however several limitations. All injuries were classified retrospectively using participant reports and discussion with the relevant medical practitioner. Due to financial restraints, it was not possible to access radiological examinations for all injuries which may have limited diagnostic accuracy. Authors were particularly interested in the large numbers of participants reporting pain during a squeeze test,

however a potential limitation was that we used a pain provocation test based on dichotomous reporting (pain: yes or no). Future research incorporating a numerical rating scale may be more accurate, particularly if teams are interested in responsive changes throughout a playing season. Finally, an interesting trend was noted that many athletes reported low scores for the HAGOS question 'Have you modified your life style to avoid activities potentially damaging to your hip and/or groin?" We can only postulate the reasons for this, but an interesting trend was that some athletes seemed to consider adoption of an injury prevention strategy as a modification of lifestyle. This may suggest that certain athletic populations require additional information prior to completing this section of the questionnaire.

4.10 Conclusion

At preseason testing, athletes with a history of HG injury had significantly lower self-reported function and were more than twice as likely to report pain during adduction squeeze, in comparison to healthy controls. There were no between group differences in age, hip ROM or adduction strength scores. Athletes with a previous injury may be predisposed to further injury due to incomplete resolution of symptoms. These findings also suggest that self-reported outcomes should be an integral component of athlete monitoring systems.

5 Chapter 5: Hip and Groin Injury Incidence in Gaelic football: A Prospective study

5.1 Abstract

Aims

Groin injuries are highly prevalent in field sports and have high recurrence rates. The aims of this paper are to describe the incidence and clinical presentation of the hip and groin injuries reported during a one season long prospective study in intercounty Gaelic football. With the secondary aims of describing injury patterns and to examine the potential influence the previously reported risk factor of a history of injury on an athletes' injury status in this season.

Methodology

Physiotherapists associated with the six teams recruited prospectively recorded hip and groin injuries throughout the season on a standardised injury reporting form. Baseline data was also collected regarding injury history. 154 intercounty gaelic footballers were monitored for a single playing season (2015). Time loss injuries to the hip or groin were recorded. Hip and groin injuries were classified per the clinical entity approach.

Study Design

Prospective study

Main outcome measure

Injury incidence per team was reported. In addition to this, patient demographics, injury history, time loss due to injury and diagnosis by clinical entity were reported

Results

154 male intercounty gaelic footballers completed the study. 17% (n=26) of participants sustained a Hip/ groin injuries over the course of a single playing season. In total 444 days were lost due to hip and groin injury. On average, each team sustained 4.33 Hip or groin injuries in this season. The mean absence for all injuries was 17.08 days (SD 23.438 (95%CI; 7.61-26.54). The mean absence for re-injuries was 21.65 days whereas the mean time loss for new injuries was 8.44 days. Those athletes who had previous history of hip or groin injury were over 5 times more likely to sustain a hip or groin injury than those with no previous injury history (RR: 5.28,95% CI; 2.58- 10.287)

Conclusions

A total of 26 injuries were reported over the course of this study. Injury rates are comparable to other sports. The risk of injury is over 5 times higher in those with a previous history of hip and groin pain A high re-injury rate was noted and days lost due to injury were higher in those with a previous injury history.

5.2 Introduction

Gaelic football is a field based amateur sport played in two teams of fifteen players over seventy minutes at intercounty level. It is the national sport of Ireland but it has growing popularity worldwide and bears similarities to Australian Rules football in its structure and style of play.

Approx. 12-16% of all injuries sustained in soccer are reported as hip and groin injuries (Werner et al., 2009). Murphy et al, (2012) published a four-year prospective study on injury in intercounty Gaelic football. This study reported a 9.4% injury rate for pelvis and groin and 3.1% for hip injuries in this cohort of athletes. Previous studies of groin pain in sport have tended to group all musculoskeletal causes of groin pain into a 'groin pain' group; this was generally due to diagnostic uncertainty (Orchard, 2015). In recent year's standardised terminology for diagnosis have been suggested (Weir et al., 2015). As reported injury recurrence rates are high, players at risk of injury need to be identified before injury prevention strategies can be applied. The first step in this process is identifying the incidence and epidemiology of injury. This leads to insights regarding the injuries sustained and mechanisms of injury as well as the cost to the sport regarding time lost due to injury. This study will follow the newly outlined reporting criteria and provide some new clinical insights into the breakdown of injuries in a population that has previously never been studied in this manner as this type of epidemiological research is lacking in the GAA population.

5.3 Aims

This study describes patterns of hip and groin (HG) injury in a cohort of gaelic footballers across one playing season. The primary objectives were to prospectively record HG injuries, subgrouping by clinical entity, injury severity, player demographic and stage of season. The secondary objective was to compare injury patterns in athletes with and without a history of HG injury.

5.4 Methodology

This study was completed over one playing season (November 2014- August 2015). At the start of the study a convenience sample of seven senior GAA teams from across

Ireland were recruited. All teams in Ulster and surrounding areas were contacted via letter and follow up phone calls. The study was approved by Ulster University Ethics committee and all participants provided written informed consent (Appendix H). A total of 180 adult male (aged 18-34 years) inter-county Gaelic footballers were recruited at the start of the 2014/15 playing season. All baseline analysis took place in the preseason period (October/ November 2014). To be eligible for inclusion, participants needed to fulfil the following criteria: Male, over 18 years of age and currently playing Senior or U21 football at inter-county level. Participants were excluded if they were not currently available for team selection due to current injury.

All players completed a standardised questionnaire (Appendix I) to determine demographics, age, current team and previous medical history. Recent research provides minimum reporting standards for clinical research on groin pain (Delahunt et al., 2015). Although the current study preceded the development of this statement, the study methodology meets all the desired criteria outlined in this paper.

5.5 Injury definition

Based on a standardised definition of injury from (Fuller et al., 2006). Participants were categorised into either cases with history of HG injury, or controls with no history of HG injury. When participants reported a history of HG injury history, we used the information within the questionnaire and liaised with the corresponding medical teams, to retrospectively categorise these into clinical entities as outlined by Weir et al., (2015) (Table 5.1).

> ‘Any physical complaint sustained by a player that results from a football match or football training, irrespective of the need for medical attention or time loss from football activities. An injury that results in a player receiving medical attention is referred to as a ‘‘medical attention’’ injury, and an injury that results in a player being unable to take a full part in future football training or match play as a ‘‘time loss’’ injury’ (Fuller et al., 2006).

Clinical Entity	Diagnostic Criteria
Adductor related	Adductor tenderness and pain on resisted adduction testing
Iliopsoas related	Iliopsoas tenderness, pain on resisted hip flexion and/or pain on stretching the hip flexors
Inguinal related	Pain located in the inguinal canal region and tenderness of the inguinal canal. No palpable inguinal hernia present. Pain with resistance testing of abdominals or Valsalva/ cough/ sneeze
Pubic related	Local tenderness of pubic symphysis and immediately adjacent bone.
Hip Related	History focusing on nature onset and location of the pain Mechanical symptoms of catching locking, clicking or giving way. Examination to include FABER and FADIR. Investigations as appropriate.

Table 5.1: Clinical entity diagnostic criteria (Weir et al., 2015)

The primary independent variable (outcome variable) was hip and groin injury. The prevalence (yes or no), number of injuries sustained (by player) and the time to first injury was recorded. HG injuries were prospectively recorded by the medical teams at each of the senior teams recruited. This was undertaken using the Metrifit injury report form (Health and Sport Technologies, Dundalk, Ireland). This consists of bespoke software and a platform that is accessible on all smartphones, tablets or desktop appliances (Appendix J). The medical staff had remote access to this platform to allow standardized and streamlined reporting of injuries. All medical staff received training on the use of the software and the diagnostic criteria to improve the quality of the reporting. The lead researcher was in regular contact with the medical staff involved to ensure ease of use and accurate reporting of injuries. The information within the injury report form is based on the gold standard, Orchard system of classification of injury (Rae and Orchard, 2007). HG injury definition followed UEFA guidelines –

> "an injury located to the hip joint or surrounding soft tissues or at the junction between the anteromedial part of the thigh, including the adductor muscle bellies, leading to a player being unable to fully participate in future training or match play" (Werner et al., 2009).

Injuries were then classified by clinical entity as outlined by Weir et al., (2015). The decision regarding which clinical entity was recorded was based on the clinical information provided by the medical team. All medical and physiotherapy staff involved was informed of the classification criteria. Imaging was used in the diagnosis where it was clinically indicated but was not requested as part of the reporting for this study. Time loss due to injury was also recorded in addition to whether the injury was reported because of training, match or an insidious onset (overuse). Injuries were classified as minimal (1-3 days), mild, (4-7 days), moderate (8-28 days) or severe (>28 days) based on the definitions from Werner et al., (2009). Exposure data was available for the teams involved; i.e. number of training sessions and matches and it was hoped to capture individual participant however due to lack of compliance from participants in recording daily exposure this information was not sufficient to use.

5.6 Statistical analysis

Descriptive statistics were completed for all quantitative results and presented as a mean with SD and 95% CI's. Chi Square analysis was completed for time loss data. Significance level was set at p=0.05.

5.7 Results

5.7.1 Demographics

A total of 180 athletes were initially recruited for this study from seven intercounty level teams. These 180 athletes completed the baseline assessment however one team was lost to follow up. The medical team failed to report injury data in this case, leaving six teams and n=154 who completed the study over the course of the season. The average age for this group (n=154) was 24.7 ± 3.23 years, with a mean weight of 81.86 ± 6.68Kg. 4.6% of the group were goalkeepers (n=7); 39.2% were defenders (n=60); 16.3% were midfielders (n=25) and 39.9% were forwards (n= 61). Of the 154 athletes who completed the study, 27% (n=42) had a history of previous hip or groin injury.

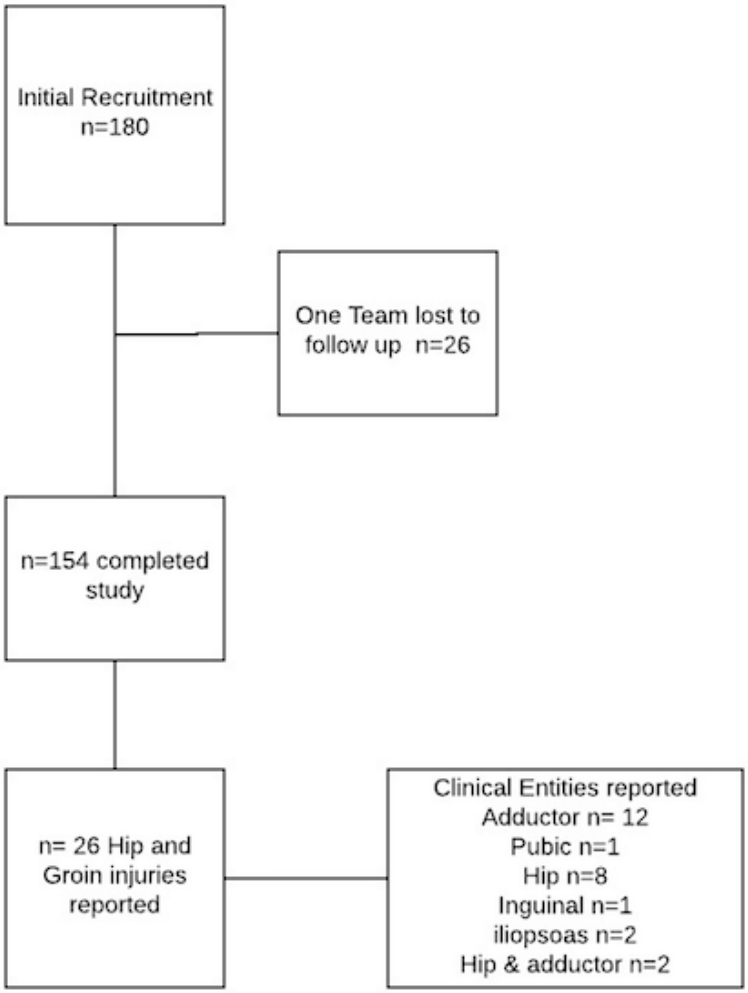


Figure 5.2: Flow diagram of study recruitment and injury reporting

5.7.2 Clinical entities

There were twenty- six HG injuries reported throughout the course of this study, equating to a 17% prevalence. Just over 75% of HG injuries were classified as adductor (n=12) or hip related pathology (n=8), with a further two athletes sustaining a multiple entity (both hip and adductor injuries). There were only small numbers of iliopsoas or inguinal pathologies recorded. The mean age of the injured players was 24.92 years (Range 20-34 years old). Forwards (n=9) and midfielders (n=8) were the most commonly injured players, followed by defenders (n=6) and goalkeepers (n=2). Acute injuries (n=14) were more common than overuse injuries (n=11), with nine injuries occurring at training at six during match play. 21-24 year olds were the most

commonly injured age group (48%), followed by 25-29 year olds (33%), with a small number of injuries in 18-20 age group (3%) and the over thirty age group (8%).

5.7.3 Injury severity

Injury severity is summarised in Table 5.2. In total 444 days were lost due to hip and groin injury (Mean 17.08, range 1-89 days, SD 23.438).

Severity of Injury	Number of days	Number of Injuries
Minimal	1-3	10
Mild	4-7	5
Moderate	8-28	6
Severe	>28 days	5

Table 5.2: Injury break down by injury severity.

5.7.4 Time Loss

The mean absence for all injuries was 17.08 days (SD 23.438) The mean absence for re-injuries was 21.65 days (total 368, range 1-89 days) whereas the mean time loss for new injuries was 8.44 days (total 76 days, range 2-19). Time loss differed in relation to site of injury, position played, age group of player and whether the injury was sustained in match or training or an overuse injury. From the table below time loss due to injury was greatest in those who sustained an adductor or hip injury. Time loss was also greater in those with overuse injuries or an acute injury sustained in a match situation. Defenders and midfielders had the greatest days lost due to injury, in addition those over 30 years of age had longer time lost to injury than their younger counterparts.

	Number	**Days lost (mean, SD, CIs)**	
		Mean (SD)	95% CI
All Injuries	N=26	17.08 (23.438)	7.61-26.54
Clinical entity			
Adductor	N=13	19.23 (22.099)	9.44-31.28
Inguinal	N=1	1.00 (-)	-
Pubic	N=1	5.00 (-)	-
Iliopsoas	N=2	5.50 (3.536)	3.00-8.00
Hip	N=8	19.67 (29.73)	3.43-41.99
Mechanism of Injury			
Training	N=9	9.89 (14.615)	2.80-21.39
Match	N=6	17.57 (22.508)	5.33-35.31
Overuse	N=11	23.20 (30.081)	7.25-43.55
Position of play			
Goalkeeper	N=2	1.5 (0.71)	1.0-2.0
Defender	N=6	26.86 (31.12)	6.83-50.98
Midfielder	N=8	19.25 (26.01)	4.4-38.43
Forward	N=9	11.0 (14.42)	4.22-21.43
Age Group			
18-20	N=1	47 (-)	-
21-24	N=13	13.77 (17.007)	6.07-24.33
25-29	N=9	14.2 (27.23)	2.17-32.00
>30	N=2	38.0 (39.59)	10.00-66.00
Previous injury			
Yes	N=17	21.65 (27.82)	9.63-35.87
No	N=8	8.44 (6.38)	4.67-12.67

Table 5.3: Breakdown of time loss by demographics.

5.7.5 Injuries reported by Month

The median number of HG injuries reported by teams was 4 (Range 1-11 injuries). Patterns of HG injuries across the season are outlined in Figure 5.3. Five players who

sustained an injury during the preseason period carried their injury from preseason into the season.

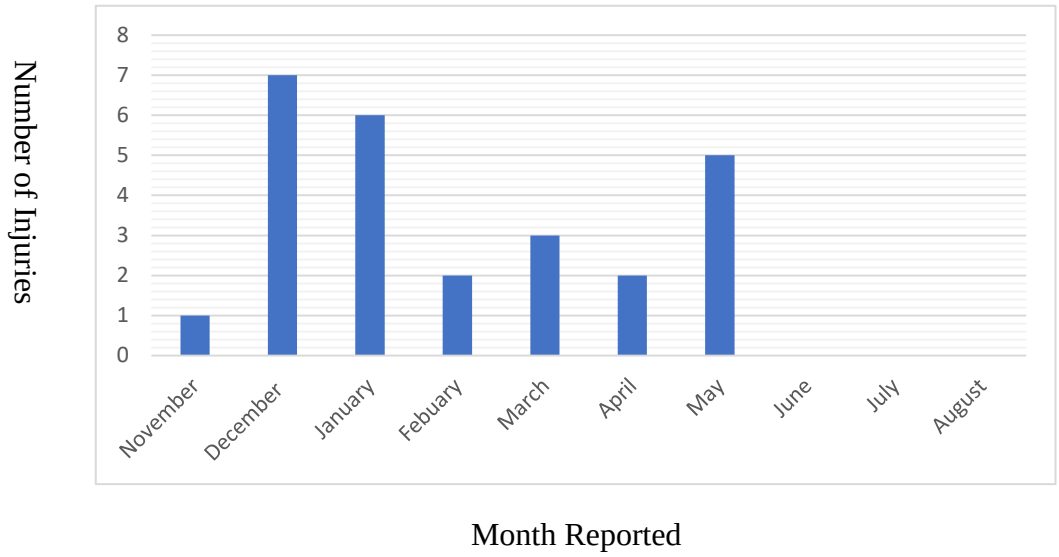


Figure 5.3: Injuries reported per month

The Gaelic football intercounty season is split into three main sections. Preseason begins in November with some preseason matches played in January. The national football league begins officially in February running through to April, with the championship tournament running between May through to September in a knockout style format. HG injury did not seem to occur uniformly over the course of the playing season with 30% (n=8) occurring in the preseason period (November and December). Six injuries were reported in January during the start of preseason matches, with fewer numbers recorded over February, March and April. Although there was a slight increase in injuries during May, no new injuries were reported in June to August. It should be noted here that some of the teams (n=4) exited the competition in June and July.

5.7.6 Previous injury

Of the players who sustained an injury in this season, n=17 of these athletes had a history of previous injury (65%). Of the seventeen athletes who had both a history of previous injury and reported an injury throughout the course of the study, 70% (n=12)

reported the same clinical entity on both occasions. Those athletes who had previous history of hip or groin injury were over 5 times more likely to sustain a hip or groin injury than those with no previous injury history (RR: 5.28 95% CI 2.58- 10.287).

5.8 Discussion

5.8.1 Prevalence of hip and groin injury.

This prospective epidemiological study is the first to quantify HG injuries in GAA footballers using the clinical entity approach. N=154 participants across six intercounty teams completed the study with n=26 injuries reported over one season, equating to a 17% prevalence. A recent systematic review (Waldén et al., 2015) reported the proportion of groin injury in soccer to be between 4-19%. Murphy et al., (2012) have previously reported that approx. 13% of all injuries in the intercounty gaelic football population were hip and groin injuries. Delahunt et al., (2016) reported 10 time-loss groin injuries in a cohort of 55 intercounty gaelic footballers (prevalence 18%) which is in line with the data from this study. Comparing gaelic football data with other footballing codes, Werner et al., (2009) and Holmich et al., (2014) report that 5% of sub elite and 20% of elite footballers sustain a hip and/ or groin injury in a season. This study reported that 17% of participants sustained a hip or groin injury, with a mean of 4.33 injuries per team per season. The mean number of injuries per team in this study is lower than those presented by Werner et al., (2009) (7.2 injuries per team per season).

A major concern of the results of this study was that 65% of HG injuries recorded were re-injuries. This is a much higher statistic than reported by Werner et al., (2009) with only 15% of their injuries to be re-injuries. However, it should be noted here that the operational definition of a re-injury by Werner and colleagues differed from that of this study. Werner et al., (2009) defined a re-injury as ‘injury of the same type and location as a previous injury that occurred within 2 months of a players return to full participation’. For the purposes of this study players were classified as ‘reinjured’ if they had reported any history of previous hip and groin injury from their demographics questionnaires. The time loss reported in this paper is longer for a re-injury than the

new injury time loss (21.65 days versus 8.44 days). This is similar to Werner et al., (2009) reporting 23 days for re-injuries versus 14 days for new injuries.

5.8.2 Clinical Entity

Adductor related injury was most common in this group, this is similar to other studies, (Hölmich, 2007, Hölmich et al., 2014, Ekstrand et al., 2011, Werner et al., 2009). In the Study by Werner et al., (2009) adductor injuries accounted for 63% of recorded injuries in elite soccer players. It was noted in this study that the number of hip injuries reported in the retrospective aspect of the study (17%) was much less than the number reported in the prospective analysis (31%). It could be argued that the increase in literature and the increase in awareness of hip joint pathology and investigation within the sports medicine community may have led to this shift in diagnosis. With the new clinical entity reporting criteria (Weir et al., 2015), there should be a more standardised approach to injury reporting in future studies. The rationale for adductor injuries being most common is unclear however the multidirectional nature of gaelic football in addition to kicking and sprinting at high speeds with an eccentric component may explain this. Rankin et al., (2015) analysed 894 hip and groin cases retrospectively and categorised these by clinical entity. In those cases, patients who participated in gaelic sports had highest numbers of adductor and hip injuries, closely followed by pubic bone stress injuries. These findings are in line with the results from this cohort and are also reflective of the other main footballing codes (soccer and rugby) as also noted by Rankin et al., (2015). Falvey et al., (2016) carried out analysis on 382 athletes presenting with groin pain. 57.9% of this group were gaelic footballers. In this gaelic football cohort they reported that 59% had pubic aponeurosis injuries, 15% adductor injuries, 22% hip injuries, 3% hip flexor injuries and 1% inguinal injuries. It should however be noted that in this study athletes had a median duration of symptoms of 36 weeks (range 8-52) and therefore it could be considered that these participants have pain of a more chronic nature than those involved in this research.

5.8.3 Seasonal Variation

The highest number of injuries were reported across December and January, with a further spike in May. This pattern may not be surprising considering the structure of

the intercounty GAA season. December signals the end of preseason with the first competitive matches played in January. Recent work completed by Hulin et al., (2016) reports an increase in injury risk with an acute to chronic workload ratio of >1.5. Although workload information is not available in this study it is logical that training load increases during preseason, with further increases just prior to the National Championships. Roe et al., (2016) completed prospective work on hamstring injury in a similar population. Their data collection started in January with a preseason period of seven weeks where 17% of injuries occurred. They noted 64% of injuries occurred in competition cycles and 19% in mid-season. This is similar to the current study which noted spiked in injury at the beginning of match cycles. However, it is to be noted that data collection began earlier in the preseason than Roe et al., (2016). Hip and groin injury in this population appears to follow a similar seasonal pattern to hamstring injury and although workload information is not available in this study, it would be a consideration for further study across a season to determine potential spikes in workload. Further work into ascertaining adequate workloads and acute: chronic workload ratios may influence these spikes in injury. Malone et al.,(2017) concluded from their study in gaelic football that high chronic training loads > 4750 AU offer a protective mechanism against injury and work to tie all these elements together would be recommended.

5.8.4 Previous injury as a risk factor for future injury.

This study reported that the risk of injury is more than five times greater if there is a history of previous injury (RR. 5.28). Thorborg et al., (2015) completed a study of 695 soccer players and reported that 49% of these had reported hip or groin pain in the previous season. Ryan et al., (2014) completed a systematic review on risk factors for hip and groin injury in sport and concluded that the most prominent risk factor was a player history of previous injury. Arnason et al., (2004) reported an OR of 7.3 for groin strains in those with a history of injury. It is not clear why previous injury carries such as significant risk of further injury however mechanisms from Ryan et al., (2014) include: remaining deficits in conditioning, scar formation, inadequate rehabilitation, altered movement patterns and premature return to play as possible reasons for an increased risk of recurring injury.

There is further evidence that altered movement patterns might be a key mechanism in recurring injury or a risk factor for injury. Franklyn-Miller et al., (2017) completed biomechanical analysis of change of direction patterns of 322 athletes with chronic athletic groin pain. They defined 3 subgroups of movement patterns however the anatomical diagnosis was not able to discriminate between the movement patterns. It must also be noted that this paper didn't use a control population of non-injured subjects. Edwards et al., (2017) completed a study on cutting task strategy in AFL players with a history of groin pain compared to controls. They reported differences decreased knee flexion and hip Internal rotation ROM, increased knee internal rotation and increased ground reaction forces during a cutting task in comparison with the control group. This paper also noted increased lumbopelvic movement during this task. AFL and GAA athletes play in very similar styles and would perform similar cutting techniques. This area of biomechanical evaluation in relation to abhorrent movement patterns may also be a consideration in the rationale of increased risk of injury in this studied population.

5.8.5 Age

The 21-34 age group were most commonly injured in this study, with the over thirty age group and under twenty group experiencing least number of injuries. This would contrast with the results of the systematic review (Chapter 2) however since completion of this review an updated review has been completed by Whittaker et al., (2015). This updated review concluded that there was no association between older age and increased risk of injury. The prospective work completed in this study would agree with Whittaker et al., (2015).

5.8.6 Playing position

Forwards were the most commonly injured group in this study, closely followed by midfielders. GPS analysis of match play by position was completed by Malone et al., (2016). Their work noted that midfielders (9523m) and half forwards (8952m) cover most distance during a game with midfielders also completing most accelerations in a game. This may go some way to explaining the number of injuries sustained in these players, however research correlating injuries sustained to distance/ sprint distances completed with GPS analysis would help confirm this.

5.8.7 Mechanism of injury.

This study did not report any significant findings in relation to mechanism of injury and diagnosis of injury. Overuse injuries typically encountered time loss of approximately 6 days more than match injuries and had considerably more time loss than training injuries (23.2 days versus 9.9 days). Overuse HG injuries frequently lead to pain and/ or reduced performance before they become a 'time loss injury' (Walden et al., 2015). This may mean that these players had a 'medical attention' injury prior to their time loss from sport. A change of injury definition to include both a time loss and medical attention definition may assist in accurate reporting of HG injuries in this population.

5.8.8 Impact of hip and groin injuries

The impact of hip and groin injuries in the GAA population can be quantified by considering the time lost to injury and the high recurrence rates of injury in this amateur sport. A total of 444 days were lost to hip and groin injury alone in this study, affecting an average of 4.3 players per team. It is also noted that recurrence of injury from previous seasons is high with 65% of hip and groin injuries in this study reporting a previous injury history. These factors are important clinically and from a team management point of view in decision making and return to play decisions. Factors that can determine increased injury risk and quantify 'at risk' players may influence individual player management strategies.

5.9 What does this study add?

This study reported a 17% prevalence of HG injury which is comparable to other studies. It was found that hip and adductor injuries accounted for 81% of HG injuries sustained. This is the first study to utilise the clinical entities approach to diagnose HG injuries in this population. This study noted a 65% re-injury rate, suggesting that previous injury remains a risk factor for new injury. This study noted an injury spike in the preseason period and again at the pre-championship period. Recommendations from these results would be further research into workload demands on players at paying particular attention to these stages of the season.

5.10 Strengths and Limitations of this study

5.10.1 Strengths

This study was conducted with a prospective design which is considered the preferred methodology for this type of research, reducing recall bias that may come from retrospective analysis.
This study followed all available guidelines to ensure methodological quality is of the highest standard. This is one of the largest studies to be undertaken in this population to date.

5.10.2 Limitations

There are several limitations to this study, firstly this study was undertaken over one playing season limiting the numbers of injuries reported and the volume of data available. The numbers for this study were relatively small given that the cohort of intercounty GAA athletes is relatively small and the constraints of being a single research centre funded study. However, this study involved athletes from Divisions 1-3 of the National football league and therefore could be considered a representative sample. Due to financial restraints, it was not possible to access radiological examinations for all injuries reported to clarify any diagnosis made.
It is noted that the previous injury history reporting was completed using retrospective recall and clinical judgement on the behalf of the researcher to define the clinical entity classification in this case. Information on timing and severity of previous injuries was not available. This may have been useful for a more in-depth analysis of results.
Within resource limitations it was not possible to fully estimate all the overuse/ non-time loss injuries. Another major limitation of this study was the lack of exposure data recorded. This facility was available for the teams involved but unfortunately compliance in recording this (by coaches/players) meant that individual exposure was not available for analysis.

Investigations were not routinely performed to confirm diagnosis in these cases however all physiotherapists and Doctors reporting the injuries consulted the consensus criteria (Weir et al., 2015), for diagnosing the injuries therefore improving the accuracy of the diagnosis. This diagnostic criterion is relatively recently published therefore leaving it difficult to make direct comparisons to other studies. The lack of clinical investigations carried out to confirm the diagnosis could be considered a limitation of this study. Injury data was only collected data in relation to hip and groin injuries therefore we are unable to report the percentage of total injury categorised as hip and/ or groin injury.

5.11 Conclusion

26 injuries were reported over the course of this study equalling a 17% prevalence. Injury rates are comparable to other sports. The risk of injury is over 5 times higher in those with a previous history of hip and groin pain. A high re-injury rate was noted and players with a history of injury reported increased time loss from sport due to HG injuries than first time injuries.

6 Chapter 6: Clinical and Self-Reported measures as Risk Factors for Hip and Groin Pain: A prospective study.

Abstract

Background

Understanding of injury causes and risks in an athletic population are prerequisites for the implementation of injury prevention strategies. Recent research has suggested that the risk factor profile of an athlete is dynamic and recursive in nature/

Aims

- To identify the prognostic ability of hip and groin clinical measures in predicting injury over a single playing season in a large cohort of athletes.
- To complete testing at two time points to analyse the dynamic nature of a risk factor profile.

Methods

154 gaelic footballers completed this study over a single playing season. Clinical testing (ROM, Adductor squeeze test and HAGOS questionnaire) and anthropometrics were administered at 2 time points. Injury data was recorded for the season.

Results

26 HG injuries were reported. History of previous injury, pain on adductor squeeze test, and reduced HAGOS scores were predictive of injury on multivariate analysis. On secondary testing, it was noted that ROM and HAGOS scores had improved from baseline and those who sustained a HG injury had significantly improved HAGOS scores.

Conclusions

Previous injury continues to be the most important predictor of future injury Clinical baseline screening tests in isolation have little value to add to a players' risk factor profile. HAGOS scores and a positive pain reproduction test may be useful measures to administer prior to applying an injury prevention programme, but at present it is still difficult to predict injury at an individual level.

6.1 Introduction

Understanding of injury causes and risks in an athletic population are prerequisites for the implementation of injury prevention strategies. This is outlined by Finch et al., (2006) in the TRIPP model of injury prevention. Chapter five worked to outline the epidemiology of hip and groin injury in the intercounty gaelic football population. This chapter introduces the next step in the TRIPP model, 'Step 2', which aims to understand the aetiology of why injuries occur, using a multidisciplinary approach and considering biomechanical factors.

The methodology of this prospective study was based on the results and conclusions of chapters two and three of this thesis. From the systematic review, it was noted that previous injury and increasing age were two non-modifiable risk factors for hip and groin injury in athletes Consideration was given that future studies should consider the cyclic nature of risk factors throughout a playing season, with a particular focus on self-reported function. The nominal group consensus study then allowed the formation of a testing protocol for the prospective study on hip and groin injury in the gaelic football population. The emerging theme from the consensus study was that the feasibility and success of the prospective study will be dependent on the utilisation of 'field' or clinical based tests instead of laboratory testing. It was decided that testing should take place twice in the season, once in preseason and once in the middle of the season as this was considered manageable, yet will allow the dynamic recursive nature of the injury risk factor profile to be explored. The methodology of testing and injury profiling has been detailed in previous chapters (Chapter 4).

Mosler et al.,(2015) completed a systematic review which analysed literature aiming to differentiate athletes with and without hip/ groin pain. They concluded that there is strong evidence for patient reported outcome measures including the HAGOS questionnaire. It also reported strong evidence for adductor squeeze as a pain provocation test but limited evidence for other methods of pain provocation including an active straight leg raise test. A weak to moderate effect was reported for internal and external ROM testing and strong evidence that a higher bent knee fall out score

(representing reduced ROM) could differentiate athletes with and without hip or groin pain. Mosler et al., (2015) looked at case control studies where players were currently injured and had matched controls. It is the aim of this thesis to take a group of injury free athletes and track them over a single season to further analyse these potential risk factors. Jovanovic, (2017) discusses the rationale for statistical modelling, that being that the use of prediction and inference are primarily to improve interventions in sports medicine. Using the clinical tests outlined in the earlier methodology (chapter 4) the aim is to measure the value of these clinical tests in a predictive capacity. The post-test probability in this case is a useful marker of clinical test value for this population. This in addition to sensitivity and specificity measures can give greater insight into clinical assessment and its value in injury prediction. Delahunt et al., (2016) completed a small-scale study in the GAA population investigating the squeeze test and HAGOS score as predictors of hip and groin injury. They concluded that a squeeze test score of below 225mmHg and a HAGOS function sport and recreation subscale score of below 87.5 were predictive of injury. They also noted that pain on squeeze test was a significant risk factor. These factors were included in this study and it is an objective of this study to carry out similar analysis to enable a comparison of outcomes. From the baseline studies and the injury reporting data it is evident that the non-modifiable risk factor of previous injury is significant in consideration of time loss post injury and risk of subsequent injury. This study aims to prospectively analyse some modifiable risk factors and provide a basis on whether screening of this kind is of benefit in this population.

6.2 Aims of this chapter

This chapter will be split into two sections for results and discussion based on the two pain aims as outlined below.

Part A

- To identify the prognostic ability of hip and groin clinical measures in predicting injury over a single playing season in a large cohort of athletes.

Part B

- To complete testing at two time points to analyse the dynamic nature of a risk factor profile.

6.3 Methodology

This chapter uses the same data as collected in the baseline study and has been described in detail in chapter four. The testing protocol was repeated in a small section of the original cohort mid-season to provide a second layer of analysis. The same clinical testing process was reproduced and players were asked to complete a further HAGOS questionnaire.

6.4 Data analysis

Data were analysed using SPSS (Version 24) where appropriate data were screened for normal distribution using Shapiro Wilk test and homoscedasticity using Levenes test. Baseline data for each predictor variable were presented as means and standard deviations for continuous data and numbers and percentages for categorical data. Initially a series of univariate analyses were conducted to determine which predictor variables were significantly associated with the dichotomous dependent variable (prospective occurrence of HG injury). Univariate analyses were t-tests and Chi_2 for continuous and dichotomous predictors respectively. Predictor variables demonstrating p values <0.2 on univariate testing were included for further multivariate analysis to explore the association between candidate risk factors and HG injury. This took the form of multivariate logistic regression models which were built using risk factor studies completed in other injury types. The first model included previous injury as it

is a non-modifiable factor, with the second model including previous injury plus any candidate variables identified from the univariate analysis. Significance level was set at $p<0.05$. R2 coefficients (Cox and Snell; Nagelkerke) were used to display the strength of the association between predictor variables with prospective HG occurrence. The strength of the predictive ability of identified factors in each model was determined using Exp(B) and its 95% CI. Tolerance values (<0.1), (Menard, 1995) VIF values (>10) (Myers, 1990) and correlations (r>0.8) were used to screen for collinearity amongst predictor variables.

6.5 Results

6.5.1 Demographics

A convenience sample of intercounty gaelic footballers (n=180) were initially recruited for this study from seven intercounty level teams. These athletes (n=180) completed the baseline assessment (November 2014). One team was lost to follow up (January 2015) as the physiotherapist failed to report injury data leaving six teams (n=154) who completed the study over the course of the season. The mean age of the group was 24.7 years (SD 3.2). Forty- two (27%) had a history of previous hip or groin injury. The mean weight of the group was 81.86Kg (SD 6.686). Of the n=154 athletes who completed the study 4.6% (n=7) were goal keepers, 39.2% (n=60) were defenders, 16.3% (n=25) were midfielders and 39.9% (n=61) were forwards.

6.5.2 Univariate Analysis

A summary of the univariate analysis is provided in table 6.1. The baseline characteristics show that those who sustained an injury during the course of the study were significantly heavier (84.8kg ± 6.4) than their uninjured counterparts (80.9Kg ± 6.6) $p=0.02$. From the baseline demographics questionnaires, it was found that 42% of those who had a history of hip or groin pain subsequently sustained an injury throughout the course of this study (OR 8.5, RR 5.28) (Chi Square 25.317 $p<0.001$). There was a significant difference in the BKFO scores between those who sustained an injury during the study and those who remained injury free ($p<0.03$). The HAGOS scores for the symptoms, pain, sport, physical activity and quality of life sub scales were all significantly lower at baseline in the group that went on to sustain an injury during the playing season ($p>0.03$). Only the ADL subsection of the HAGOS questionnaire did not reach significance at this stage (=0.13).

The mean value for squeeze test was 171.9 mmHg (SD 27.4; 95% CI 167.4, 175.9). When analysing baseline scores and its relationship to injury status, there was no significant difference in adductor squeeze scores for those who subsequently sustained (169.7±29.0 mmHg) and those who didn't sustain a HG injury (172.4 ± 27.2mmHg), (p= 0.657). In the analysis of pain provocation on squeeze test at baseline testing and injury status, 25.4% of those who reported positive for pain at baseline squeeze testing sustained an injury during the study. (OR 2.33, RR 1.992, Chi Square 3.996 p=0.046).

Variable	**Sustained injury**		**P value**
	Yes n=26	No n=126	
CONTINUOUS			
Body weight (kg)	84.8 (±6.4)	80.9 (±6.6	P=0.02*
Left Internal rotation (Degrees)	20.2 (± 6.0)	21.3 (±5.8)	P= 0.35
Right internal rotation (Degrees)	20.4(±6.5)	21.9 (±5.7)	P =0.23
Left external rotation (degrees)	26.1(±6.7)	25.5 (±4.9)	P= 0.59
Right external rotation (degrees)	27.9 (± 5.8)	25.9 (5.2)	P= 0.09
Left BKFO (cm)	17.2 (± 5.4)	19.6 (±5.1)	P= 0.03*
Right BKFO (cm)	16.8 (±5.24)	19.4 (±4.7)	P= 0.01 *
Average Squeeze (mmHg)	169.7 (± 29.0)	172.4 (± 17.2)	P= 0.64
HAGOS Symptoms	79.4 (±11.9)	85.2 (± 12.2)	P = 0.02 *
HAGOS Pain	77.4 (± 17.7)	87.0 (± 17.7)	P= 0.01*
HAGOS ADL	87.8 (± 13.2)	92.1 (± 13.7)	P= 0.13
HAGOS Sport	70.1 (±20.0)	87.4 (±16.2)	P= 0.00*
HAGOS Physical Activity	68.9 (± 31.1)	89.3(± 16.9)	P=0.003*
HAGOS QOL	64.6 (± 26.9)	84.5 (±17.7)	P= 0.001*
DICHOTOMOUS			
N (%) with previous injury	18 (69.2)	24 (19.0)	
N (%) with pain on squeeze	15 (55.5)	44 (34.9)	

Table 6.1: Results of Univariate analysis

6.5.3 Logistic regression

In consideration of the variables selected for logistic regression, the factors that were significant on univariate testing ($p<0.2$), were included in the multivariate model. These were; history of previous injury, pain on adductor squeeze test, BKFO scores and the results from the HAGOS questionnaire. On testing for collinearity, all HAGOS scores were very closely related, as such only the total score was utilised in this multivariate model. This model was completed in blocks. Block one included previous injury (non-modifiable variable) and the other modifiable variables were added in block 2 (BKFO scores, HAGOS total score and presence of pain on squeeze test). As shown in tables two and three, both models in block one and block two were significantly ($p<0.001$ and $p<0.05$ respectively) better than the baseline (null) model.

Block 1

		95% CI for exp b		
	B (SE)	Lower	Exp b	Upper
Included				
Previous injury	2.13 (.47)**	3.37	8.42	21.03

Note R^2 = .14 (Cox and Snell), .23 (Nagelkerke).

Model X^2 (1) = 22.54 , p< .0001

**P<.0001

Table 6.2: Logistic regression

Block 2

		95% CI for exp b		
	B (SE)	Lower	Exp b	Upper
Included				
Previous injury	1.58 (.54)*	1.70	4.60	13.90
LBKFO	-.003 (.08)	.85	.99	1.17
RBKFO	-.11 (.08)	.75	.89	1.06
Total HAGOS	-.005 (.003)	.99	.99	1.00
Pain on Squeeze	.37 (.50)	.54	1.44	3.83

Note R^2 = .14 (Cox and Snell), .23 (Nagelkerke).

Model X^2 (5) = 31.35 , p< .0001

*P<.005

Table 6.3: Logistic regression block 2

Block one suggests that this model can explain 23% of injuries based on previous injury history. (R^2 =0.23). It also explains that the odds ratio for sustaining an injury is 8.42 times higher if you have a previous injury. In block two the Nagelkerke R^2 value remains at 0.23 therefore the conclusion can be drawn that the addition of the other factors into the model does not improve its predictive capacity.

In block two, the Beta co-efficients for the continuous variables are all negative values, therefore suggesting that a decrease in their scores is associated with an increased risk of injury. This means that a lower HAGOS score (wald = 3.075 p= 0.08) and an increased ROM in BKFO (wald= 0.001; left p= 0.989, and wald =1.568 right p=0.210) are associated with increased injury risk, however in the multiple regression analysis this did not reach significance. The dichotomous variables included in the regression analysis provided a positive beta co efficient result, however when included in the multiple factor model only previous injury remained significant. When considering the interactions between the predictor variables included, the OR for previous injury drops to 4.582 (wald 8.661 p=0.003). The other dichotomous variable considered (pain on squeeze test) does not reach significance (wald 0.534 p=0.465), however the odds ratio suggests that presence of pain on squeeze indicates that the athlete is 1.4 times more likely to sustain a hip or groin injury than those who have a negative pain provocation result on this test.

Observed		**Predicted**		
		Sustained Injury		% correct
	Sustained Injury	No	Yes	
Pre	No	125	0	100
	Yes	26	0	0
	Overall			82.2
Post	No	119	6	95.2
	Yes	19	8	29.6
	Overall			83.6

Table 6.4: Observed versus predicted results.

The classification table (table 6.4) above compares the likelihood of sustaining an injury pre- and post application of the regression model. If it is assumed that no one sustains an injury 82.2% of athletes correctly will be classified correctly. Once the model is applied this increases but only by 1.5% to 83.5%, it is therefore questionable if this model is clinically significant.

6.5.4 Pre-and post-test odds

Pre- and post-test probabilities provide a measure of the value of a clinical test, which is of huge importance in sports medicine and the application of clinical tests as a baseline measure. Using data previously reported by Delahunt et al., (2016) looking at a cut off point for the HAGOS sport subscale, the same cut off point of 87.5 was utilised in this study and it was hypothesised that those scoring below this would leave players at increased injury risk. This analysis yielded a positive likelihood ratio of 1.87 (Sensitivity 0.741; Specificity 0.603) Increasing the post-test odds of predicting injury from 18% to 23% (95%CI 23-35%). Testing for previous injury in this manner yielded a positive likelihood ratio of 3.5 (95% CI 2.24- 5.48) and increases post - test odds of correctly predicting injury to 43% (95%CI 32-54). When analysing the subjective markers that were significant in the assessment, history of previous injury, positive for pain on adductor squeeze and HAGOS sport <87.5 and tabulated those who were positive with at least two out of three measures. The positive likelihood ratio was 2.46 (95% CI; 1.7- 3.56) (sensitivity of 0.704 specificity of 0.714), increasing post-test probability to 35%. When all three measures were positive at baseline injury the positive likelihood ratio increased to 5.19 (95% CI 2.33-12) this increases the post-test probability to 53% (95% CI 33-72) and provides a test with specificity of 0.929 and sensitivity of 0.37. The nomogram below (figure 6.1) shows the likelihood of correctly predicting injury if all three tests are positive versus all three tests negative. Prior to any testing athletes are at an 18% risk of sustaining an injury, in gathering our baseline injury information the odds of correctly predicting injury can be increased to 53% if all three tests are positive.

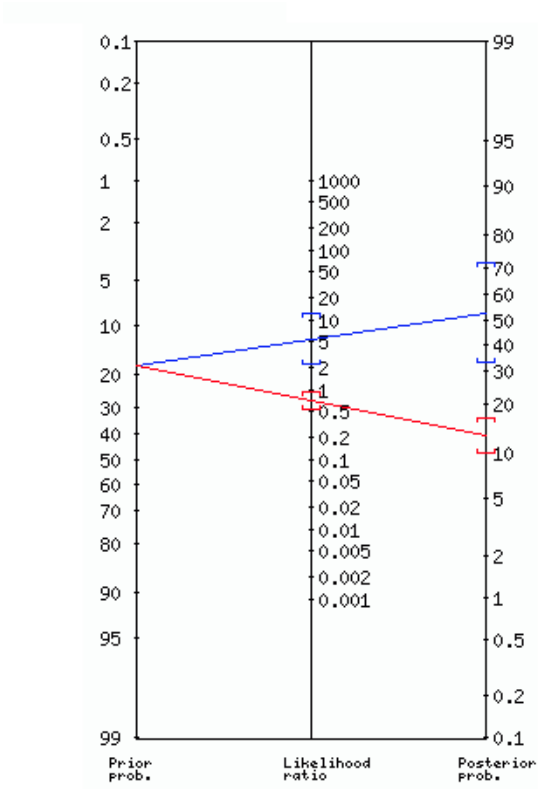


Figure 6.1: Nomogram showing pre-and post-test odds when considering 3 positive tests. (previous injury, pain on squeeze and sport subscale of HAGOS of <87.5)

6.6 Discussion

This study is the largest study to date in this population which has prospectively examined hip and groin injury risk factors. From the results, it was found that previous injury, pain on squeeze test, decreased HAGOS scores and increased BKFO scores were significantly different in injured subjects on both univariate analysis and multivariate analysis. On further analysis, it was noted that using simple subjective measures of injury history, pain on squeeze and a HAGOS sport subscale score of <87.5 yielded a positive likelihood ratio of 5.19 and post-test odds of 53%. This could be a meaningful clinical application of the results of this study.

6.6.1 HAGOS

Delahunt et al., (2016) used a ROC curve to detect an optimal cut of point to discriminate between players based on their injury status. This was reported at 87.5 in

the function, sport and recreation subscale and an associated positive likelihood ratio of 2.56. This study repeated this analysis on a larger cohort, but the same population as Delahunt et al., (2016). The same cut off point was used as the previous work. In this larger cohort, the associated positive likelihood ratio was 1.87 suggesting that the use of this discriminatory value to predict injury may be of use, however the original paper may have overestimated the effect of this test. Thorborg et al., (2013) provided 95% reference ranges for injury-free soccer players in their HAGOS subscale scores. The mean values reported in this study fall within these reference ranges on all subscales for the non-injured participants in this study. When looking at the mean values for the participants who subsequently sustained an injury the mean values on the pain, sport, physical activity and quality of life subscales were all below the reference ranges reported by Thorborg et al., (2013). This further strengthens the evidence that the HAGOS questionnaire is a valuable preseason patient reported outcome measure in the identification of players at risk of a hip and groin injury. Bahr, (2016) suggests that once a cut-off point is identified, that this point needs to be reapplied to a new population to confirm the association between risk factor and injury risk and to test the performance of the cut off provided. This study agrees with the cut-off point suggested however the original value of this cut off may be overestimated.

6.6.2 Squeeze test

The mean value for squeeze test was 171.9 mmHg (SD 27.4; 95% CI 167.4, 175.9). when considering baseline scores and its relationship to sustaining an injury the mean score for those who sustained an injury was 169.7mmHg (SD 29.0) and those who didn't sustain an injury was slightly higher (172.4 ± 27.2mmHg). This result did not reach significance (p= 0.657). Delahunt et al., (2016) suggested a cut-off point of below 225mmHg as a predictor of hip and groin injury. This study doesn't support this finding. It was found that a positive pain response on squeeze testing is a significant risk factor for injury, however in isolation is a poor predictor of injury. Pain on squeeze has been investigated further since this study was completed and recent research by Thorborg et al., (2017) discussed the use of a 5 second squeeze and pain quantified using a traffic light system. They used a safe group (NRS: 0-2), acceptable (NRS: 3-5) and high risk (NRS: 6-10) to quantify the results of the squeeze test. Their

study reported correlation between NRS scores with the adductor squeeze and HAGOS sport subscales. This correlation was quantified with an NRS of 0-2 scoring a median of 97 (86-100; 25-75 centiles) NRS 3-5 scoring a median of 65 (56-84) and an NRS of 6-10 correlating with a HAGOS sport score of 47 (31-61). In this current study, the pain rating was not quantified, which could be considered a limitation of this study. It was found that pain on squeeze at baseline testing was a significant risk factor for a subsequent hip or groin injury in the subsequent season (OR 2.33, RR 1.992 , Chi Square 3.996 p=0.046). It may be subject of further research to quantify the level of pain using an NRS and considering this classification system in a clinical setting alongside the HAGOS questionnaire and injury history. It may also be a relevant clinical test for the ongoing monitoring of players on return to play to try and reduce the high recurrence rates reported for hip and groin injury.

6.6.3 ROM/BKFO

There was no significant difference in hip rotation measures between the injured and uninjured participants in this study. Mosler et al.,(2017) published normative values of hip strength and ROM in a professional soccer population. Although direct comparisons are not available for most ROM measures due to differing methodologies, the same BKFO methodology was utilized. In soccer BKFO measures tend to be better than those in a GAA population. This current study reports mean BKFO scores of between 16.83cm (±5.24) and 19.56± 5.05), whereas Mosler and colleagues, (2017) reported a dominant BKFO as 13.1±4.5cm and non-dominant as 13±4.3cm. Both measures showing increased flexibility than the current athletes despite injury status. A small case control study was carried out using a similar demographic of player by Nevin and Delahunt., (2014). This study reported reduced hip internal and external rotation in the injured group in comparison to the control group. The same methodology was utilized on ROM measuring between the two studies however our results did not report the same loss of ROM for those who sustained an injury during the season. This may be explained as none of the current athletes were injured at the time of testing at either testing point. It may be considered that ROM may fluctuate in at risk players. Further investigation of this factor in the form of regular ROM testing throughout a season may be warranted to analyse this further.

6.6.4 Regression model

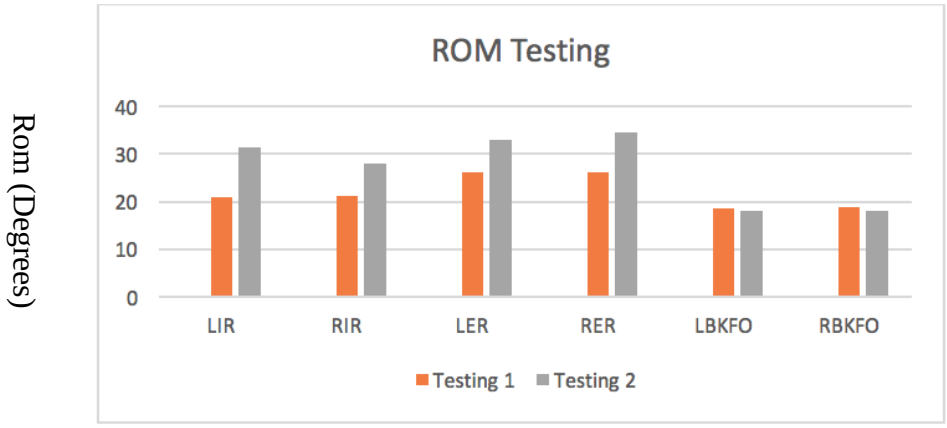
Due to the level of collinearity the total HAGOS score was used in the multivariate analysis. The addition of the modifiable factors although still a significant model, failed to improve the strength of the model.

6.7 Part B: Analysis of a dynamic risk factor profile

A convenience sample n=65 (42% of the original sample) across three of the five teams were re-tested mid-season (May, 2015). The same testing protocol was outlined as in testing one, (see chapter four for details). The results of the testing between the two time points are outlined below. Between groups comparison were completed using paired sample t tests and between groups ANOVA to provide statistical analysis of this data.

6.7.1 ROM Testing

On retesting ROM, all rotation scores tended to increase (figure 6.2). There was a significant difference between the scores on testing times one and two for internal rotation (both left and right) and external rotation (both left and right). These four measures recorded significance levels of $p<0.001$. There was no significant difference in the bent knee fall out scores between the two testing days (left; $p=0.372$, right $p=0.08$)



ROM measures

Figure 6.2: Differences in ROM testing between testing one and two

A repeated measures ANOVA for within subjects testing (sustained injury) revealed no significant difference in testing scores for all ROM measures when controlling for previous injury (wilks Lambda .848 p=0.153, Partial eta Squared 0.152).

6.7.2 Adductor Squeeze testing

Mean adductor squeeze test results didn't change between testing one (173.8 ±28.229mmHg) and testing two (172.5±33.45mmHg) for the n=65 athletes retested. On completing the repeated measures ANOVA for the mean squeeze test value this was not reach significance (wilks lambda .997, p=0.686 Partial eta Squared 0.003) despite the groups being approximately 10mmHg lower on this scale at both testing points (figure 6.3).

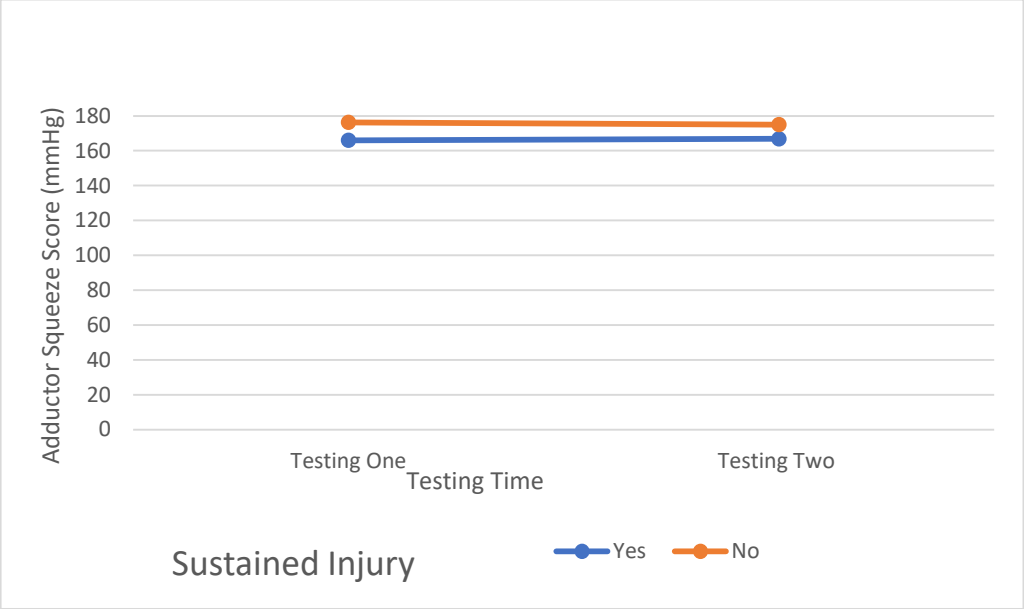


Figure 6.3: Adductor squeeze test values between testing one and two (mmHg)

6.7.3 Pain on Squeeze test

The tables below (tables 6.5 & 6.6) show the frequency of reporting pain on the adductor squeeze test for the 65 participants who were testing twice in this study. From testing one the odds ratio of sustaining an injury if answering yes to the pain on

adductor squeeze test question was 1.373 (95%CI 0.706-2.668) (Chi Squared: 0.344 p=0.558). On testing two the odds ratio had increased to 2.22 (95% CI 1.12- 4.402), however this did not reach significance (Chi Squared= 3.385 p=0.06).

Sustained injury	**Pain on Squeeze test (testing one)**		**Total**
	Yes	No	
Yes	7	8	15
No	17	33	50

Table 6.5: Pain provocation on adductor squeeze test (testing one)

Sustained injury	**Pain on Squeeze test (testing two)**		**Total**
	Yes	No	
Yes	8	7	15
No	12	38	50

Table 6.6: Pain provocation on adductor squeeze test (testing two)

6.7.4 HAGOS Questionnaire

When comparing the overall HAGOS Scores between testing one and testing two all subscales showed a tendency to increase in score however only the sport subscale showed a significant change (p=0.024).

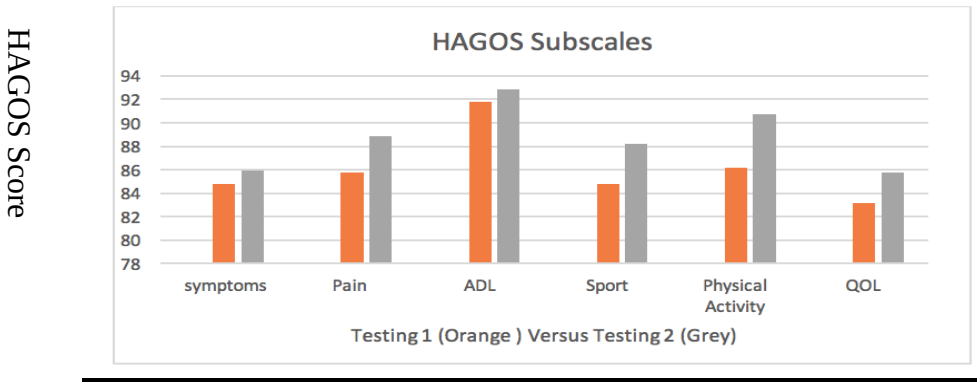


Figure 6.4: HAGOS questionnaire scores at testing one and testing two for n=65.

When considering the mean differences between those who sustained and injury and those who did not, Independent samples t-testing was completed looking at the differences in the clinical measures between time one and time two. All subscale scores tended to Increase from testing one to testing two if the athlete sustained an injury in the interim period. All results were statistically significant except the ADL subsection. The increase in scores ranged from an average of 5.3 points to 20 points. In this section also completed a repeated measures ANOVA where total HAGOS Score as well as the sport subsection were further analysed.

Total HAGOS score increased from 462.4 (SD 83.2 95% CI 418.3, 506.59) to 545.6 (SD 60.0 95%CI 506.7, 584.6), for those who had sustained an injury in the interim period. Those who didn't sustain an injury in the interim period didn't see the same increase in score 532.31 (SD 86.2) during initial testing and 528.4 (SD 79.2). This proved significant on RM ANOVA testing. (Wilks Lambda .876, p= 0.008 Eta Squared .106)

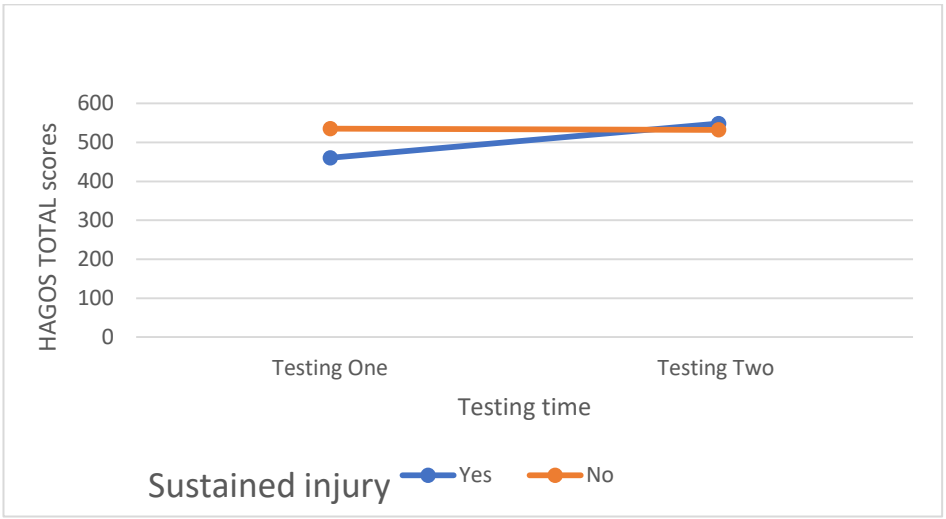


Figure 6.5: Plot of Total HAGOS scores at testing one and testing two based on injury status.

When analysing the sport subscale of HAGOS at preseason there was a difference in the scores based on subsequent injury status. (Injured 74.6±15.75 versus uninjured 87.87±17.1) On second testing this score had significantly increased for those who

sustained an injury. (Wilks Lambda 0.924, P=0.027 Partial eta Squared 0.076). whereas those who didn't sustain an injury maintained a similar score (figure 6.5).

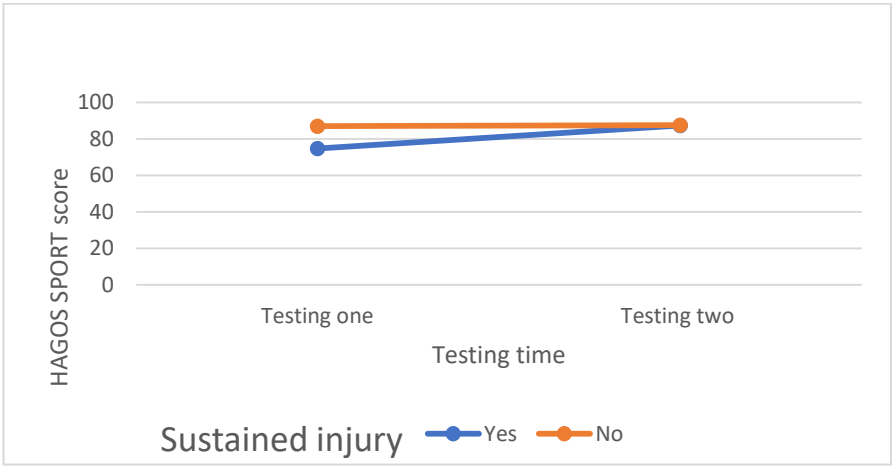


Figure 6.6: Plot of HAGOS sport subscale at testing one and testing two categorised by injury status.

It is of note at this stage that none of the athletes who were retested were considered 'currently injured' at the time of testing. HAGOS specifically asks regarding symptoms within the last 7 days of injury and all athletes were not reporting carrying an injury at the time of retesting.

6.8 Discussion

This is the first time that a secondary testing period was administered in a prospective study of this population. The same methodology was undertaken in a mid-season training period to a convenience sample of sixty-five of the original cohort.

6.8.1 HAGOS Questionnaire

In this study the HAGOS questionnaire was re-administered to a convenience sample (n=65) of the original cohort in the mid-season period. In the interim fifteen of the sixty-five participants had picked up a hip or groin injury. On analysis of the first results in comparison to the second results it was noted that the players who subsequently sustained an injury during the season had significantly lower baseline scores. On second testing the fifteen players who had sustained an injury in the interim

period had went through rehabilitation and were returned to play. When analysis was completed comparing the first and second testing results in relation to injury status it was found that after their injury this groups scores were increased similar to those of their uninjured counterparts. Clinically this appears to suggest that rehabilitation strategies seem to be adequate at least in the short term to improve subjective scores of symptoms, pain and sport functioning, however it is not possible to draw conclusions as to the longevity of these rehabilitation measures and whether they maintain good HAGOS scores by the end of the season or the start of the following season. This could suggest that longer term monitoring of these 'at risk' players could be warranted and using a HAGOS questionnaire appears to be a sensitive measure of subjective sporting function at baseline and in the short term. A longitudinal study of this nature would be suggestion for further research.

6.8.2 Adductor Squeeze Test

This study reports a slight increase in odds ratio between testing one (1.3) and testing two (2.2) with pain on squeeze test, however this did not reach significance (p=0.06). Thorborg et al., (2017) completed a study where baseline and second testing were completed in soccer players. The second testing was optional in their group for anyone who sustained hip or groin pain throughout the season. In their study a long lever squeeze test was utilized and a numeric rating scale given to the quantification of pain response. 0-2 considered 'safe' 3-5 considered acceptable and 6-10 considered 'at risk'. Thorborg et al., (2016) concluded that there is a correlation between reduced HAGOS sport scores and a higher pain reproduction score with the five second squeeze test. Their study didn't show a significant difference in the number of players complaining of pain with a short lever squeeze test between testing times, despite changes in the HAGOS sport score. This suggests that a NRS scale for pain reproduction may be a more sensitive measure in monitoring 'at risk' players throughout a season. It is to be considered due to the findings of this study that one single risk factor or clinical test will not give us a clear picture of a player's risk of injury. Agreement with Hegedus et al.,(2016), would be suggested, where they state that in principle constructs that are protective or risk factors for an injury are most likely multidimensional, involving complexities beyond those of a single physical

performance test. However, it can be concluded that it is still difficult to predict hip and groin injury at an individual level in an athletic population from baseline measures.

6.9 Limitations

The main limitation of this study was that we were unable to provide individual exposure data. This was due to non-compliance with the measurement technique by coaches and players. It is also a consideration that due to baseline testing that these scores may not remain stable across a playing season as is the nature of modifiable risk factors. Regular monitoring would be warranted in this situation to enable researchers to build a dynamic picture of each players' risk factor profile.

6.10 Strengths

This is the one of the largest studies to be undertaken in this population and the only study to date which provides retest data. Finch et al., (2006) in the TRIPP model noted that there is a need for the sports injury research field to move away from analysis of just one team or one sporting event. This study has achieved this by including analysis from six teams across a season and two testing points. The methodology of this paper and the selection of the risk factors were based on two previous studies, a systematic review and a nominal group consensus study. This strengthens the rationale behind risk factor selection, reproducibility and application into clinical settling considerably

6.11 Conclusion

This study is the largest of its kind in this population. From these results, it is noted that previous injury continues to be the most important predictor of future injury. It is also noted that clinical baseline screening tests alone have little value to add to a players' risk factor profile. HAGOS scores and a positive pain reproduction test may be useful measures to administer prior to applying an injury prevention programme, but at present it is still difficult to predict injury at an individual level.

7 Discussion

The aim of this thesis was to investigate the etiology of hip and groin injury in sport through prospective examination of dynamic risk factor profile and injury incidence in GAA athletes. This was completed through three strands of research: A systematic review; a nominal group study to gain consensus on relevant risk factors in GAA population and methods of monitoring in this population and finally a prospective study to determine how risk factor profile changes across a playing season using a large cohort of gaelic football athletes and how this relates to injury incidence.
This chapter will reflect on the study results in its entirety using the conclusions from previous chapters and recommendations for further work in this area.
From the findings of the systematic review there was a suggested need for a research project in this population which would explore the risk factor profile of the athletes in a dynamic and recursive manner. Whilst the systematic review highlighted the non-modifiable risk factors of previous injury and increasing age as a risk factors for further injury. Inconclusive evidence was presented for several modifiable risk factors including strength and ROM measures. All appropriate data was pooled for meta-analysis which confirmed the results of the narrative review. In the absence of empirical evidence, it was then decided to form a nominal group study to ascertain the format of the further aspects of the research. The successful outcome from the nominal group study yielded a methodology that was deemed applicable and relevant in this population using reliable and valid outcome measures.

7.1 Utilisation of a Nominal group technique to gain consensus on study methodology.

The use of a nominal group study aiming to gain consensus on testing methods in a prospective study was successful in this research project. There was a lot of enthusiasm expressed by the participants that this type of research was to be carried out in the gaelic football population as this hadn’t previously been studied. The participants identified many interesting talking points and were very engaging in their

discussion and participation in the study. It was felt that the aims of the nominal group study were achieved and from this piece of work, the researchers could develop clearer ideas on the testing methodology and feasibility. It is felt that the nominal group technique is an adequate methodological technique for studies of this kind. In comparison to using a Delphi technique it was felt it was more time efficient yet yielded the same outcomes. The main theme that was noted during the study was that clinicians wish to be able to utilise the results of the research being carried out and if successful implement a testing/ monitoring protocol with their athletes. During discussions, an overarching theme was evident that the clinicians involved felt that the methodology should be easily repeatable 'in the field' and on a regular basis. Moreover, it should be reliable and not involve great expense to the player or expensive equipment (e.g. lab equipment such as isokinetics, optogait, etc.) which is not easily accessible.

The clear and meaningful discussion held on this study evening was a strength of this study. This has been noted previously by Harvey and Holmes, (2012) which stated that the collaborative nature of a nominal group study serves to increase the participant's ownership of the ensuing research and therefore increases the likelihood of changing clinical practice and policy. It is noted that in further studies of this kind that involvement of all service users (athletes/ coaches/ sports science professionals) may be of benefit to further inform the methodology of prospective studies. This would further maximize engagement in research of this kind and may facilitate data collection procedures.

To the authors knowledge this is the first time that hip and groin clinical and patient-reported outcomes have been analysed prospectively in a large cohort of GAA athletes. 180 participants were recruited from seven intercounty teams across Ireland. Baseline clinical measures were available for these players. Demographic data aligns with earlier demographics reported in Gaelic Football (Nevin and Delahunt, 2014, McIntyre, 2005). Testing was undertaken in the preseason period prior to the 2014/15 playing season with a follow up testing period completed mid- season (April/ May 2015). Epidemiological data for HG injury in gaelic footballers has been produced using the using the clinical entity approach as per the Doha consensus statement (Weir et al., 2015). 154 participants across six intercounty teams completed the epidemiological and prospective study with n=26 injuries reported over one season,

equating to a 17% prevalence. This is slightly lower than recent data reported by Mosler et al., (2017) of a 21% prevalence in soccer. Delahunt et al., (2017) reported 10 time-loss groin injuries in a cohort of 55 intercounty gaelic footballers (prevalence 18%) which is in line with the data from this study. The mean number of injuries per team was 4.33 over the course of the season which is lower than statistics presented by Werner et al., (2009) (7.2 injuries per team per season). The impact of hip and groin injuries in this population can be quantified by considering the time lost to injury and the high recurrence rates of injury in this amateur sport. A total of 444 days were lost to hip and groin injury alone in this study, affecting an average of 4.33 number of players per team. It is also noted that recurrence of injury from previous seasons is high with 65% of hip and groin injuries in this study reporting a previous injury history. An injury spike was noted in the preseason period and again at the pre-championship period, which may have adversely affected player availability and team performance. Recommendations would therefore be made for further research into workload demands on players paying attention to these stages of the season. These factors are important clinically and from a team management point of view in decision making for team selection and return to play decisions. Epidemiological factors that can determine increased injury risk and quantify 'at risk' players may influence individual player management strategies.

This study reported that the risk of injury is more than five times greater if there is a history of previous injury (RR. 5.28). This has been reported on numerous occasions in previous literature. Thorborg et al., (2015) completed a study of 695 soccer players and reported that 49% of these had reported hip or groin pain in the previous season. Ryan et al., (2014) completed a systematic review on risk factors for hip and groin injury in field based sport and concluded that the most prominent risk factor was a player history of previous injury. Arnason et al., (2004) reported an OR of 7.3 for groin strains in those with a history of injury. It is not clear why previous injury carries such as significant risk of further injury however mechanisms from Ryan et al., (2014) include: remaining deficits in conditioning, scar formation, inadequate rehabilitation, altered movement patterns and premature return to play as possible reasons for an increased risk of recurring injury. Recent work by Shrier et al., (2017) states that a return to preinjury state may include factors beyond strength range of motion, balance and psychology. They suggest that the M-FASIS model could be incorporated in the

management of risk upon return to play and notes that injury risk may change over time independent of injury. This paper notes this as important as tests of physical capacity will never be fully representative of the physical stresses the athlete will incur once returning to the actual sport and RTP decision making should include concepts related to work overload, this type of work has yet to be completed in this population and would be a consideration for further research.

7.2 Clinical measures

The HAGOS questionnaire was administered at two time points in this study. The HAGOS questionnaire is the most common PRO measure used in the assessment of HG function. In comparing normative values for healthy soccer players (Thorborg et al., 2014), it is noted that values in the gaelic football population are slightly lower irrespective of injury status. Mosler et al., (2015) suggest that PROs, such as HAGOS, can accurately distinguish players with and without groin pain. In a study of 695 sub elite male soccer players Thorborg et al., (2015) found that players with previous pain or injury, had lower scores across all sub constructs of HAGOS, compared to uninjured controls. Similarly, in this population it was found that athletes with a history of HG injury scored consistently lower than controls across each of the HAGOS subscales. Work by Delahunt et al., (2016) suggests that the function, sport and recreation subscales have a strong predictive validity for HG injury, based on cut point of 87.5 (positive likelihood ratio of 2.56). Using the baseline data from this study and additional exploratory analyses using dichotomised scores, only 33.1% of participants with a history of injury reached the 87.5 threshold suggested as a cut off for the sport, function and recreation subscale. In contrast, 71% of the control reached this threshold. When this analysis was completed using the prospective data collected the associated positive likelihood ratio was 1.87 suggesting that the use of this discriminatory value to predict injury may be of use. Bahr, (2016) suggests that once a cut-off point changing a continuous variable to a dichotomous variable is identified, that this point needs to be reapplied to a new population to confirm the association between risk factor and injury risk and to test the performance of the cut off provided. This study fulfilled this criteria and therefore adds to the current pool of research in agreement with the suggested cut off point by Delahunt et al., (2016).

A unique component of this thesis was the re-administration of the HAGOS questionnaire mid-season to n=65 of the original cohort. Interestingly, 24% of this sample had sustained a HG injury in the interim period (between baseline and mid-season) and successfully returned to play. On analysis of the first results (baseline) in comparison to the second results (midseason) it was noted that the players who subsequently sustained an injury had significantly lower baseline scores than their uninjured counterparts. Interestingly their scores were much improved after rehabilitation and return to play and comparable to their uninjured colleagues who maintained similar scores between testing points. Clinically this appears to suggest that rehabilitation strategies seem to be adequate at least in the short term to improve subjective scores of symptoms, pain and sport functioning, however it is not possible to draw conclusions as to the longevity of these rehabilitation measures and whether they maintain improved HAGOS scores by the end of the current season or the start of the following season. This could suggest that longer term monitoring of these 'at risk' players could be warranted and using a HAGOS questionnaire appears to be a sensitive measure of subjective sporting function at baseline and in the short term. The HAGOS questionnaire also appears to be sensitive to change in athletes who have undergone a rehabilitation period. It would be suggested that a repeated measure of HAGOS or a modified version of the same could be included in player monitoring strategies as baseline screening no longer appears adequate to analyse a dynamic risk factor profile in this population. A longitudinal study of this nature would be suggestion for further research. Further work should also address the level of change required in HAGOS scores to be considered clinically significant.

The adductor squeeze test has been used extensively in the literature to assess adductor strength in athletic populations. Nevin and Delahunt, (2014) recorded significantly lower adduction strength scores in a cohort of gaelic footballers with groin pain (202.88mmHg), when compared to uninjured controls (269.33mmHg). This current study noted that athletes with a history of injury were significantly more likely to have pain on squeeze testing, however did not record any between group differences in strength. There is evidence from a recent systematic review (Mosler et al., 2015), that patients with ongoing HG pain are significantly more likely to report pain on a squeeze test (OR 4.31, 95% CI 1.86 to10). The cases in the current study had a history of HG pain, but nonetheless, they were still more than twice as likely (OR 2.23 95% CI 1.16;

2.49) to report pain on a squeeze at baseline testing in comparison to controls with no history of HG pain. It was concluded that a positive pain response on squeeze testing is a significant risk factor for subsequent injury, however in isolation is a poor predictor of injury. Pain on adductor squeeze has been investigated further since this study was completed and recent research by Thorborg et al., (2017) discussed the use of a 5 second squeeze and pain quantified using a traffic light system. They used a safe group (NRS: 0-2), acceptable (NRS: 3-5) and high risk (NRS: 6-10) to quantify the results of the squeeze test. Their study reported correlation between NRS scores with the adductor squeeze and HAGOS sport subscales. In this current study, the pain rating was not quantified, which could be considered a limitation of this study. It was found that pain on squeeze at baseline testing was a significant risk factor for a subsequent hip or groin injury in the subsequent season (OR 2.33, RR 1.992, Chi Square 3.996 p=0.046). It may be subject of further research to quantify the level of pain using an NRS and considering this classification system in a clinical setting alongside the HAGOS questionnaire and injury history. It may also be a relevant clinical test for the ongoing monitoring of players on return to play to try and reduce the high recurrence rates reported for hip and groin injury.

No significant differences in hip ROM were noted based on previous injury status. Previous reviews have also found conflicting evidence linking ROM and hip and groin injury (Whittaker et al., 2015). Pooled results from 3 high quality studies found that hip pain was associated with small limitations in hip ROM (3.7 degrees in IR) and BKFO (3.6cm) compared to controls (Mosler et al., 2015). In contrast, Tak et al., (2016) found no differences in hip ROM (combined IR and ER) and BKFO between painful and pain free hips. A small case control study was carried out using a similar demographic of player by Nevin and Delahunt, (2014). This study reported reduced hip internal and external rotation in the injured group in comparison to the control group. The same methodology was utilized on ROM measuring between the two studies however the results of this study did not report the same loss of ROM for those who sustained an injury during the season at either testing point. This may be explained as none of the athletes were injured at the time of testing at either testing point in this study whereas Nevin and Delahunt, (2014) completed a cross sectional study using currently injured and non-injured players. It may be considered that ROM may fluctuate in at risk players and again strengthens the argument that the risk factor

profile of a player is fluid and cannot be captured in its entirely with baseline screening. Further investigation of this factor in the form of regular ROM testing throughout a season may be warranted to analyse this further.

Bahr, (2016) suggests that to make screening tests useful in clinical practice, a continuous variable must be translated to a dichotomous outcome, whether the athlete is at increased risk or not (yes/ no) and capture the majority of athletes with increased injury risk so they can utilise the opportunity to complete targeted training programmes. From the results of this study it was found that utilising simple subjective measures of pain on squeeze test, and a HAGOS sport score of <87.5 in addition to a previous injury history of HG pain can increase the odds of correctly predicting injury from 18% to 53%. This is a simple cost effective clinical measure. In the context of application to a team it may be of more benefit to reduce the criteria to two out of three of these measures testing positive as a cut off for the 'at risk' group. The rationale for this is that using 2/3 as a clinical measure yields a sensitivity of 0.704. On testing all three measures positive the sensitivity of the test decreases to 0.37 therefore potentially not capturing all 'at risk' players for inclusion in injury. The next step in the injury prevention process would be to apply this finding in a longitudinal cross sectional or RCT study where players were monitored for HAGOS and pain provocation scores and injury prevention programmes planned accordingly. Another suggestion would be regular monitoring of HAGOS scores throughout the season, as it is evident from the results of the second testing that this measure is sensitive to change pre-and post-injury and could be used in this population to potentially pre-empt an injury based on lowering scores. This would need further investigation to clarify the longitudinal value of measuring HAGOS and a user- friendly method of regularly completing this questionnaire or a modified version of the same.

7.3 Strengths and Limitations of this study

7.3.1 Strengths

This study was conducted with a prospective design which is considered the preferred methodology for this type of research, reducing recall bias that may come from retrospective analysis. This study followed all available guidelines to ensure

methodological quality is of the highest standard. This is the first study in this population and injury type that included more than one testing point in its methodology, this recurrent monitoring rather than baseline screening would be recommended for further research. This is one of the largest prospective studies to be undertaken in the amateur gaelic football population. The structure of this thesis in its entirety adds to the robustness of the methodology, taking the results of a systematic review and consensus study to inform an applicable and clinically relevant methodology for this population. The structure of this study allowed the results to give a preseason/baseline measure of athlete status, included a season long epidemiological study as well as second period of testing to allow for a secondary analysis of health status.

7.3.2 Limitations

There are several limitations to this study, firstly this programme of research was undertaken over one playing season limiting the numbers of injuries reported and the volume of data available. The numbers for this study were relatively small given that the cohort of intercounty GAA athletes is relatively small and the constraints of being a single research centre funded study. However, this study involved athletes from Divisions 1-3 of the National Football League and therefore could be considered a representative sample. Due to resource restrictions, it was not possible to fully estimate all the overuse/ non-time loss injuries. Another limitation of this study was the lack of exposure data recorded. This facility was available for the teams involved but unfortunately compliance in recording this meant that individual exposure data was not available for analysis. Injury data was only collected data in relation to hip and groin injuries therefore we are unable to report the percentage of total injury categorised as hip and/ or groin injury. Injury histories were classified retrospectively using participant reports and discussion with the relevant medical practitioner. The pain provocation aspect of the adductor squeeze test reporting produced some interesting results, however a potential limitation was that the pain provocation test based was on dichotomous reporting (pain: yes or no) rather than a quantitative score. Perhaps future research incorporating a numerical rating scale may be more accurate, particularly if teams are interested in responsive changes throughout a playing season.

7.4 Suggestions for further research

This piece of work utilized a case control methodology to report the baseline results of this cohort of athletes, this then formed a prospective cohort study which was one season long.
Prospective methodology is the preferred reporting format for this type of research (Delahunt et al., 2015). Minimum reporting standards for studies of this kind have recently been produced (Delahunt et al., 2015). This study notes that STROBE guidelines should be utilized in studies of this kind (Von Elm et al., 2007). It is felt that there is value in both case control and cohort studies when undertaking research of this kind. In the use of a case control study the research focuses on those with the injury in comparison to their uninjured counterparts and can give a snapshot of the health status of the athlete at that time. This is useful for isolating potential differences in health status that can then be monitored for change, either positive or negative. In the case of prospective cohort studies the athletes can be tracked over a specified period to allow other potential variables to become apparent and their interaction with training/ match load and health status to be identified. It is felt that in future studies of this kind that a combination of both types of methodology are utilized to on larger scale to further inform research and clinical practice in this area.

Further research in this area should focus on patient reported outcome measures such as pain rating and HAGOS scores. In the professional sport setting a readiness to play or train type questionnaire which incorporated results of a squeeze test and potentially modified HAGOS questions could be useful in detecting fluctuating symptoms in a dynamic environment. This has not been investigated to date in relation to injury risk. This could be a relatively simple method of reporting real time risk at either a group or individual level.

8 Conclusion

This study is the largest study to date in this population which has prospectively examined hip and groin injury risk factors. From the systematic review, it was concluded that there was a dearth of evidence for monitoring of athletes across a season and that a history of previous injury remains a prominent risk factor for injury. From the results of the prospective study, it was found that previous injury, pain on squeeze test, decreased HAGOS scores and increased BKFO scores were significantly different in injured subjects on univariate analysis. On further analysis, it was noted that using simple subjective measures of injury history, pain on squeeze and a HAGOS sport subscale score of <87.5 yielded a positive likelihood ratio of 5.19 and post-test odds of 53%. This could be a meaningful clinical application of the results of this study. It is noted that HAGOS scores can change over time with rehabilitation/ intervention. This should be a subject of further research and its application into player monitoring systems. It is concluded that it is still difficult to predict injury successfully at an individual level however these tests may be useful in the administration of an injury prevention programme at team level and incorporated into an athlete monitoring system.

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10 Appendices

10.1 Appendix A: Search terms used in Systematic Review

Athlete/
Athlet*
Sport/
Sport*
exp exercise
Exercis*
Inguinal region
Groin
Groin adj8 (Pain or Strain or tear or Injur*)
Adductor Adj8 (Pain or Strain or tear or Injur*)
osteitis pubis.mp
pubic bone stress injury .mp
inguinal hernia
inguinal adj4 hernia
abdominal injury
abdominal adj8 (Pain or Strain or tear or Injur*)
Gilmore8 adj1 groin
posterior inguinal wall deficiency.mp
hip injury
Hip adj8 (Pain or Strain or tear or Injur*)
Hip adj8 impingement
labr* adj8 (Pain or Strain or tear or Injur*)
iliopsoas adj8 (Pain or Strain or tear or Injur*)
hip flexor adj8 (Pain or Strain or tear or Injur*)
Femoroacetabular impingement
FAI. Mp
Femoroacetabular adj1 impingement
Risk or risk factor
Risk.mp
Caus*.mp
Pred.mp

10.2 Appendix B: Search Strategy Used in Systematic Review

Database	Search term	Number of results	Articles retrieved
Embase (1990-present)	Groin OR adductor OR osteitis pubis AND injury AND sport AND risk factor	39	35
	Hernia OR abdominal OR gilmores groin OR Posterior inguinal wall deficiency AND injury AND sport.	69	9
	Hip OR hip impingement OR labral tear AND injury AND sport AND risk factor	136	21
	Iliopsoas OR hip flexor AND injury AND Sport	68	8
Medline (1990-present)	Groin OR adductor OR osteitis pubis AND injury AND sport AND risk factor	45	8
	Hernia OR abdominal OR gilmores groin OR Posterior inguinal wall deficiency AND injury AND sport	61	6
	Hip OR hip impingement OR labral tear AND injury AND sport AND risk factor	93	8
	Iliopsoas OR hip flexor AND injury AND Sport	3	0
Cinahl (1990-Present)	Groin OR adductor OR osteitis pubis AND injury AND sport AND risk factor	25	2
	Hernia OR abdominal OR gilmores groin OR Posterior inguinal wall deficiency AND injury AND sport	26	0
	Hip OR hip impingement OR labral tear AND injury AND sport AND risk factor	772	3
	Iliopsoas OR hip flexor AND injury AND Sport	12	0
TOTALS		1349	53

10.3 Appendix C: Included studies Characteristics

Study	Participant demographics	Risk Factors examined	Outcome measure	Significant Risk Factors reported	Non-sig RF reported	Injury incidence (when reported)
Wuitrouw et al (2003)	Belgian soccer players (n=146) over 1 season N=13 adductor injuries	Flexibility: adductors	Injury rate		Adductor (p=0.45) Gastrocnemius (p=0.72)	9% of players sustained an adductor injury.
Orchard (1998)	12-14 AFL teams and 5-10 u-18 AFL teams	Age	Injury rates	RR=2.07 (younger players more at risk)		25 injuries per 10000 hours in AFL players, 51.7 injuries per 10000 in U18
O' Connor (2004)	Professional rugby league players (N=100) 23 groin injuries reported	Demographics: • Age • Playing experience • Level of ability • Weight training experience Kinanthropometric measures ROM Flexibility	2 year monitoring for injury site severity and mechanism of injury	Greater weight ($p<0.05$) Smaller dominate femur diameter ($p<0.001$) Non dominate adductor PT 3.6 rad ($p=0.03$) Non dominate ad PT 0.52 ($p<0.001$)	Height, playing experience, side stepping, level of competition, position played. Body fat, Thigh girth; ROM IR, ER, Abd, Add; FABER; Peak hip add, knee flexor, and extensor concentric torque.	23% injury rate with incidence of 2.4 per 1000 hours.

		Isokinetic testing				
Hagglund et al, (2013)	26 professional soccer teams followed over 9 seasons (n=1401) 523 injuries were reported	Anthropometric data, Previous injury history, playing position and match related Variables. • Type of match & venue • Period of season • Climate region	Injury rates, location, severity, time loss.	Previous injury (HR 1.48, p=0.02) Goalkeeper (HR 0.58, p=0.048) Away matches (HR 0.56 p<0.001)	Anthropometrics Other match related factors.	
Holmich et al (2013)	Sub elite male soccer players (n=998) 58 groin injuries reported in 54 players.	Anthropometric data. Injury history Position played	Injury rates over 10 month season and time loss via injury reporting form	Previous injury (HR 2.13, p=0.0068)	Anthropometrics	0.4 injuries per 1000 hours
Slavotinek et al, (2005)	AFL players (n=52) 22 injuries reported.	Preseason groin pain Focal tenderness MRI	Training restriction and games missed due to groin pain	Pubic bone tenderness (*P* = .02), and linear parasymphyseal T2 hyperintensity (*P* = .01) were associated with restricted training capacity during the subsequent season. Preseason groin pain (*P* = .03) was associated with missed games		22 athletes (42%) reported groin pain with n=9 missing matches due to groin pain
Schick et al (2003)	6 male and 6 female university hockey teams	Preseason medical forms. Injury report forms and attendance records. Gender	Athlete exposure and Time loss due to injury.	Nil	No difference in injury risk and gender.	7.9% females and 8.8% males experienced adductor strain

	n= 261 22 adductor injuries					
Arnason et al (2004)	Elite male football players (n=306) 32 groin injuries. (13%)	Anthropometrics Flexibility Jump height Peak 02 uptake Knee/ ankle stability Previous injury history Player exposure	Injury report form, player exposure	body fat (p=0.02). older age (p=0.02) previous injury (OR: 7.3 p=0.001) Decreased ROM hip abduction (OR 0.9 p=0.05)	height, BMI, Weight, power and peak O2 uptake.	
Engebretsen et al (2010)	Amateur male soccer players (n=508) 61 injuries affecting 51 players.	Self report questionnaire (general information/ injury hx/ Groin outcome score) Specific testing (isometric adductor strength measurement/ CMJ test/ 40m sprint test) Clinical examination (by expert clinicians using FIFA preseason medical assessment)	Injury reports Exposure to matches and training	Individual as unit of analysis) Age (OR1.61 P=0.001) Countermovment jump (OR 1.36 p=0.05). Each leg as unit of analysis Previous injury (OR 2.46 p=0.002) GROS total and subsections symptoms, soreness and pain (OR 1.12- 1.27) p< 0.05) Hip External rotation ROM (OR1.53 p<0.01) Weak adductor Strength (adjusted OR 4.28 p=0.02) Referred pain in abdominals on	On multivariate analysis only previous injury (adjusted OR 2.6) and weak adductors (adjusted OR 4.28) were significant.	0.6 injuries per 1000 hours. 1.8 per 1000 match hours 0.3 per 1000 training hours.

				functional testing (OR 14.6 p<0.001) Pain on testing of iliopsoas (OR 3.8 p=0.01) Weakness of iliopsoas (OR 5.18 p=0.01)		
Hagglund et al (2006)	Elite male soccer players (n=525) over 2 seasons. 194 injuries	Training and match exposure Anthropometrics Injury history	Injury rates	Previous injury (HR: 2.4; p<0.01)	Age, height, weight, BMI	194 groin injuries were recorded (incidence of 1.1-1.3 per 1000 hours)
Tyler et al, (2001)	NHL male players (n=58) 11 adductor strains were recorded in 8 participants. All injuries occurred in match situations	Preseason examination • Hip Flexibility • Thomas test • Strength (MMT using dynamometer)	Between group analysis of those who sustained injury v those who remained uninjured	Adductor strength 18% lower in players who subsequently sustained a groin injury (p=0.021). no difference was noted between the injured and uninjured sides in these participants (p=0.18). Adduction: abduction strength ratio was significantly lower in the injured group (P=0.038) (95% v 78%). In the injured group adduction: abduction ratio was lower on the subsequently injured side than uninjured (P=0.011) (86% v 70%). RR for an adductor strain was 17:1 based	Flexibility measures	3.2 injuries per 1000 player- game exposures.

				on a hip adduction of less than 80% of abduction strength.		
Steffen et al (2008)	Female adolescent soccer players (n=1430). 19 injuries reported	Anthropometrics Questionnaire covering participation and current function. Groin outcome score. Injury history.	Injury rates over subsequent 8 months	Previous injury (RR1.6; p=0.04)	Anthropometrics Groin outcome score	1% of participants sustained a groin injury.
Emery & Meuwisse (2001)	NHL players (n=1292) 52 injuries reported (13.3% reinjuries)	Training questionnaire isometric hip adductor torque Flexibility measurements: hip abduction; Previous injury, level of NHL experience, position of play, Athlete exposure, skate blades		<18 sport specific training sessions in the off season (RR3.38) previous injury (RR, 2.69).	sport specific training (regular season) peak isometric adductor torque or total abduction flexibility	
Crow et al (2010	Elite youth AFL players (16-18) n=86.	Hip adductor muscle strength measured weekly	Onset of groin pain	The mean hip adductor strength of injured players was significantly decreased from baseline by an average of 11.75±2.50% in the week of injury onset (p< 0.001) and 5.83± 5.16% in the week preceding the onset of groin injury (p=0.004.)		

Verrall et al (2007)	AFL male professional players (n=29) Age 18-30 years N= 4 injuries	Anthropometrics IR and ER ROM Testing at baseline	2 year injury follow up	Lower body weight (p=0.02), decreased total ROM (p=0.030)	Internal Rotation External rotation Age Height	4/ 29 players were injured. No incidence data available.

10.4 Appendix D: Quality assessment Criteria

Question	Quality assessment
Study groups are clearly defined	Positive if truly or somewhat representative of the average population.
Number of cases of 50 or more	Positive if the total number of cases was greater than or equal to 50.
Adequacy of follow-up of cohorts	Positive if complete follow-up: all subjects accounted for, and positive if subjects lost to follow-up; unlikely to introduce bias, number lost of less than 20% in 3 months, or description of those lost suggests no difference from those followed.
Comparable groups	Positive if the study controls are comparable for age and gender
Prospective cohort studies	Positive if the study design was a prospective cohort study.
Inclusion and exclusion criteria	Positive if inclusion and exclusion criteria were described.
Follow-up period of 6 months or more	Positive if follow-up period was greater than or equal to 6 months.
Definition of determinant and outcome	Positive if a clear definition of determinant and outcome was described
Analysis and data presentation	Positive if the assessment method was suitable.
Data presentation	Positive if risk estimates were presented or when raw data were given that allow the calculation of risk estimates, such as odds ratio or relative risks.
Consideration of confounders	Positive if the confounders that were considered were described.
Control for confounding	Positive if the method used to control for confounding was described.

10.5 Appendix E: Letters of invitation to Nominal Group study

Dear_____

Please find attached information regarding a research project that you may be interested in participating in. The study is a qualitative analysis of the risk factors for hip and groin injury in male Gaelic footballers. You have been chosen as a potential participant due to your experience in this field and it is felt that you could contribute greatly to the outcome of this study.
This study is being conducted as part of a larger study into the risk factors for hip and groin injury in male Gaelic footballers and will be used as part of a PhD project by Helen Mc Elroy.

Please contact Helen Mc Elroy on 07889319468 or mcelroy-h@email.ulster.ac.uk if you require further clarification on any of the information given

Yours Sincerely,

Helen Mc Elroy

PhD student
Ulster Sports Academy
University of Ulster
Jordanstown

What are the key risk factors for Hip and Groin Injury in the GAA: A nominal group study

Participant information sheet

My name is Helen Mc Elroy, I am a physiotherapist and PhD student at the Ulster Sports Academy, University of Ulster Jordanstown. My PhD is an investigation of the risk factors for hip and groin injury in GAA. I wish to invite you to take part a section of this research project.

Before you decide whether or not to take part it is important you understand what the aims of the research are and what you will be asked to do.
Please read the following information and if you have any questions please do not hesitate to ask about anything that may not be clear to you.
Thank you for taking the time to consider this invitation.

What is the Purpose of this study?
There is currently little clear information from research to describe why hip and groin injuries are so common in GAA sports. We are undertaking a research study to find out what experts think about hip and groin injury in GAA; we are particularly interested in finding out what factors might increase the risk of hip and groin injury.

Why have I been chosen?
We are interested in gaining insight from medical staff involved in GAA. You have been asked to participate in this study as it is felt that you have expertise in this area and could contribute to this study. There will be approx. 8-10 other participants in the group.

Do I have to take part?
Participation is entirely voluntary. If you do decide to take part you will be given this information sheet to keep and you may be asked to sign a consent form. If you choose to participate, you can change your mind at any time and withdraw without explanation.

What will happen if I do take part?
You will be invited to attend the Group session taking place in the University of Ulster Jordanstown on _____. Throughout the day you will be asked to provide your opinion on a number of topics relating to hip and groin injury in the GAA. There are no right

or wrong answers; we are most interested in your personal experience and opinion. This session will be led and facilitated by Dr Chris Bleakley, Dr LeeAnn Sharp and Helen Mc Elroy. You will be provided with detailed directions to the campus closer to the time. The session will last approximately 4-5 hours, with regular breaks and refreshments/ lunch will be provided for you. The main questions that will be discussed and debated on the day will be:

1. What are the most important risk factors associated with hip and groin injury in GAA?
2: What is the most appropriate method of monitoring these risk factors?

Risks/ Disadvantages

You will be giving up your time to participate in this study. If you chose to be involved in the study you are not required to report any personal or sensitive information about yourself. You must not communicate any personal or sensitive information about a named third party eg. patient, player or team mate.

Are there any potential benefits in taking part?

By taking part in this group discussion there may be a learning opportunity for participants by reflecting on their own practice and by drawing on the experience of others. This could help to provide a better service for athletes. The information generated from this research will help to inform further research in this area.

What happens when the study ends?

All participants will be provided with a detailed report of the group discussions and a copy of the final results.

Will my taking part in the study be kept confidential?

Yes, the names of those who have participated in the research will not be published.

What will happen to the results of the study?

This study will be used for the part fulfilment of a PhD. Some results may be published in an academic journal. It will primarily be used to inform future work in the prevention of hip and groin injury in GAA.

Who is organising and funding the research

The main investigator is Helen Mc Elroy. Funding for the PhD has been from a DEL Studentship with the Ulster Sports Academy.

Who has reviewed this study?

This study has been peer reviewed and approved by the University of Ulster Ethics Filter Committee (Ulster Sports Academy).

Contact details

If you wish to take part in this study or for further information or Please contact Helen Mc Elroy (07889319468)

10.6 Appendix F: Nominal Group Consent and Demographics Questionnaire

Participant Questionnaire

Please answer the following Questions

Name:

Qualifications:

No. years experience working with GAA athletes:

Team Currently Involved with?

Do you complete any monitoring of your GAA athletes for hip and Groin injury?

If so, please detail tests/ regularity of monitoring/ Method of addressing issues (e.g. training modification/ prehabilitation etc)

What are the key risk factors for hip and groin injury in the GAA? A nominal group study

Consent Form

Helen Mc Elroy (PhD student and Facilitator)

I confirm that I have been given, have read and understood the information sheet for the above study and have asked and received answers to any questions raised.

I understand that my participation in this study is voluntary and that I am free to withdraw at any time without giving a reason and without prejudice.

I understand that the researchers will hold all information and data collected securely and in confidence and that all efforts will be made to ensure that I cannot be identified as a participant (except as might be required by law) and I give permission for the researchers to hold relevant personal data. I understand that this study may be video-recorded for the purposes of data collection

I consent to take part in the above study

_____ _____ _____

Name of Participant ***Signature*** ***Date***

_____ _____ _____

Name of person taking consent ***Signature*** ***Date***

_____ _____

_____

Name of researcher ***Signature***

Date

One copy for the participant; one copy for the researcher.

10.7 Appedndix G: Working Definitions used in Nominal Group Study

Working Definitions for use throughout the study

Please refer to these for clarification:

Prospective research: All data is collected in a standardised manner, prospectively in time. The approach involves measuring potential risk factors before injuries occur, after which new cases and exposure are reported during a period of follow up.

Intrinsic risk factors: predisposing factors that act from within (internal), to increase the risk of injury . (Bahr et al, 2003)

Extrinsic Risk Factors: Predisposing factors that act on the athlete from outside (External), to increase the risk of injury (Bahr et al, 2003)

Clinical Entities **(Holmich et al, 2007)**

Adductor-related pain: Palpatory pain at the muscle origin at the pubic bone and pain with adduction against resistance

Iliopsoas-related pain: Palpatory pain of the muscle through the lower lateral part of the abdomen and/or just distal of the inguinal ligament and pain with passive stretching during Thomas' test

Rectus abdominis-related pain: Palpatory pain of the distal tendon and/or the insertion at the pubic bone, and pain at contraction against resistance

Hernia: The presence of a visible and/or palpable inguinal mass and/or when a massive cough impulse was present

Sports hernia: No hernia present (as described above) as well as tenderness of the external inguinal ring and tenderness in the area of the conjoint tendon and close to its insertion at the pubic tubercle

Hip joint pathology: The differential diagnosis for patients who present with hip joint abnormalities and have normal plain radiographic findings include, synovitis, labral tears, loose bodies, degenerative disease, ligament teres tears and chondral defects. (Mitchell et al, 2003)

10.8 Appendix H: Participation information and Consent form

Participant Information sheet

Risk factors for Hip and Groin injury in Male Intercounty Gaelic Football

You are being invited to take part in a research study. This research study is being led by a group of researchers at the University of Ulster.
Before you decide whether or not to take part, it is important that you understand what the research is for and what you will be asked to do. Please read the following information and do not hesitate to ask any questions about anything that might not be clear to you. Make sure that you are happy before you decide what to do. Thank you for taking the time to consider this invitation.

What is the purpose of the study?
The purpose of this project is to record the injuries that occur during the Gaelic football Intercounty 2014/15 season. Recording this information will help us to answer the following important questions:

- How often hip and groin injuries occur in intercounty Gaelic football?
- How many games/ training sessions do players miss due to injury?
- What are the most important factors contributing to injury (eg. Strength, flexibility, players' age, height, weight, amount of training completed)?

This information is important as it will help to determine where and when injuries are most likely to happen and how we can avoid them in the future

Why have I been chosen?
You have been asked to participate in the study for the following reasons:

- Your team have agreed to support the study.
- You are aged over 18 years of age at time of enrolment
- You are a member of your Senior/ u21 intercounty football team,
-

Do I have to take part?
No; although your team have agreed to support this study, it is up to YOU to decide whether or not to take part. If you do decide to take part, you will be given this information sheet to keep. Both you and your managers will be asked to sign a consent form. If you choose to take part, you can change your mind at any time and withdraw from the study without giving a reason at any time.

What will happen to me if I take part?
If you choose to take part in this study you will have to do the following:
1). Complete a short questionnaire and some screening tests to assess strength, Flexibility, lumbopelvic control at 3 set times during the 2014/15 playing season. The questionnaire will record your date of birth, usual playing position, body mass, body height, dominant leg and arm, and injury history. You will be given a unique player registration number which will be used to identify you throughout the study. This will ensure that your details remain confidential (ie. your information can only be identified by the researchers involved in the study).

2). If you sustain a hip or groin injury playing gaelic football between 1st October 2014 and 1st October 2015 you should report this injury to a member of the medical staff involved with your county team. This person will be either a member of your coaching staff, or your team's physiotherapist/ Doctor. They will be identified to you prior to the start of the season. When you report an injury to them they will ask you: the date of the injury, how the injury occurred and the body part that is affected. This information will be entered into an online database and filed under your unique player registration number.

3.) You will be instructed in the use of an online diary which you will use to record the duration and the level of exertion during training sessions. It is expected that you fill this out on a daily basis.

Are there any risks and/or disadvantages?
There is a risk of injury when playing sports such as gaelic football, however taking part in this study will not cause any additional risks or disadvantages.

Are there any possible benefits in taking part?
There will be no direct benefit to the participants who are taking part. However, the information gained from this study will help doctors, physiotherapists and coaches to determine where and when injuries are most likely to happen and how we can avoid them in the future. In the future this can help to reduce the risk of injury in those who play Gaelic football.

Will my taking part in this study be kept confidential?
You will be given a unique player registration number which the researchers will use to identify you throughout the study. Any personal information you provide or any details on the injuries that you sustain will be held securely within a password protected computer and a locked cabinet and will only be accessible by the chief investigator (Dr Chris Bleakley) and primary investigator (Helen Mc Elroy). Any identifiers will be removed prior to publication as required under Data Protection legislation. The Freedom of Information legislation allows access to certain non-personal or generalized data.

What will happen to the results of the study?
The results of the study may be published in a peer reviewed medical journal. Personal data will NOT be published. Data from a single team will NOT be published. The results of the study will be used to develop an injury prevention programme for Gaelic footballers

Who is organising and funding the research?
This research is being undertaking as part of a PhD project funded by a DEL scholarship and through the University of Ulster. The student completing this research is Helen Mc Elroy (Chartered Physiotherapist)

Who has reviewed this study?
This study has been peer reviewed and passed by the University of Ulster ethics filter committee.

Contact details
If you have any questions about the study or should you require any additional information on this research study, please contact:

Helen Mc Elroy
Physiotherapist and PhD Student
Room 15C09
University of Ulster
BT37OQB
Tel: 07889319468
Email: mcelroy-h@email.ulster.ac.uk

Risk factors for Hip and Groin injury in Male Intercounty Gaelic Football: A Prospective study

Consent Form

Helen Mc Elroy (PhD student and Primary investigator)

I confirm that I have been given, have read and understood the information sheet for the above study and have asked and received answers to any questions raised.
I understand that my participation in this study is voluntary and that I am free to withdraw at any time without giving a reason and without prejudice.
I understand that the researchers will hold all information and data collected securely and in confidence and that all efforts will be made to ensure that I cannot be identified as a participant (except as might be required by law) and I give permission for the researchers to hold relevant personal data.
I consent to take part in the above study

_____ _____ _____

Name of Participant ***Signature*** ***Date***

_____ _____ _____

Name of person taking consent ***Signature*** ***Date***

_____ _____ _____

Name of researcher ***Signature***
Date

One copy for the participant; one copy for the researcher.

10.9 Appendix I: Participant Questionnaire

Player Questionnaire

Personal details

Name:

Date of Birth:

Occupation

Commute to Work

To training

Sport Specific questions

Team Played for: Club

County

Other (University/ dual player etc)

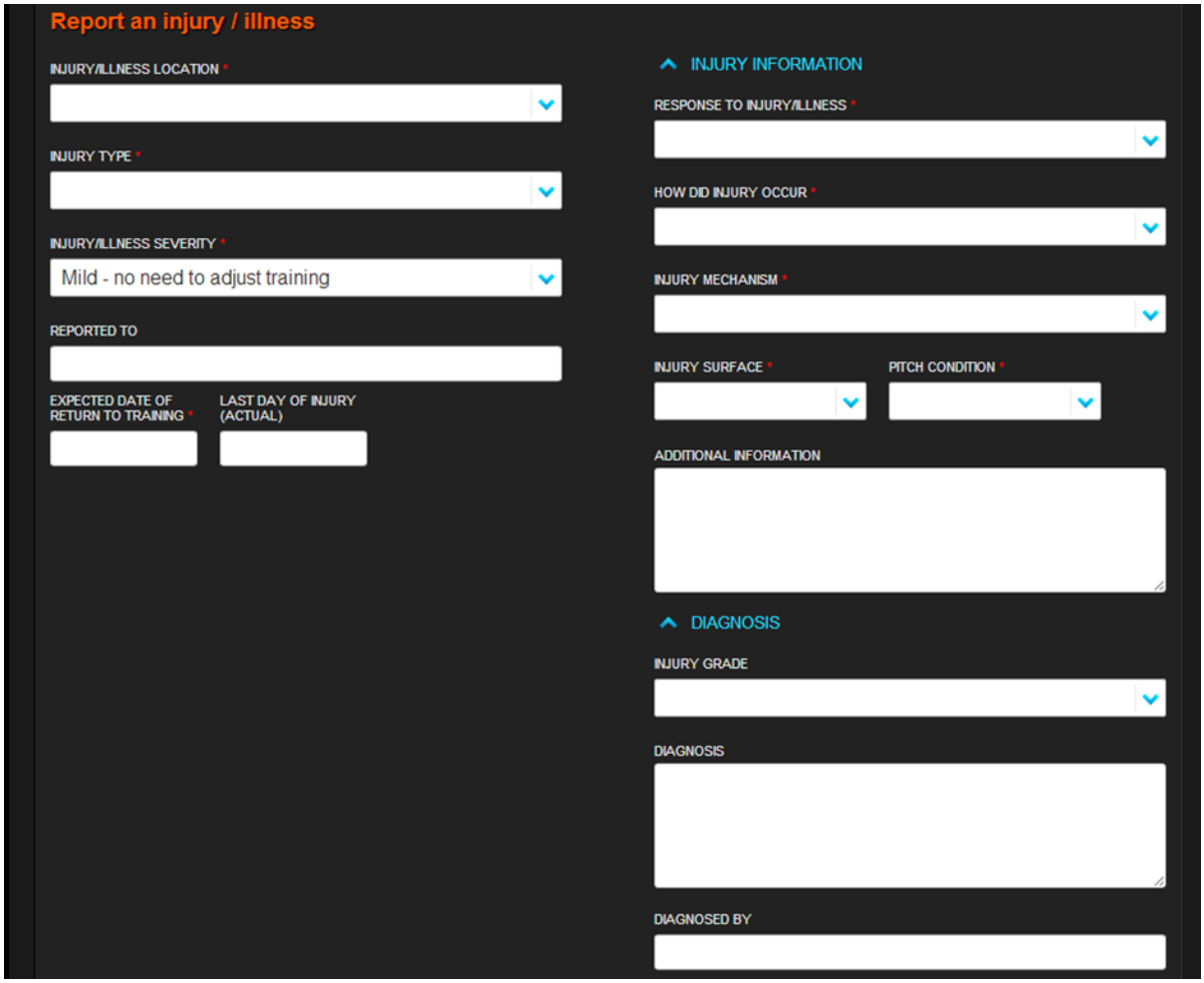
Position played:

Dominant side (Left or Right) :

Previous injuries (please list diagnosis if known and left or right side (if applicable)

Previous surgery: (Please indicate approx. dates of surgery, and return to sport)

10.10 Appendix J: Injury Recording Template using Metrifit Software



10.11 Appendix K : HAGOS Questionnaire

HAGOS Questionnaire concerning hip and/or groin problems

Today's date: _____/_____/_____ Date of birth: _____/_____/_____

Name: _____

INSTRUCTIONS: This questionnaire asks for your view about your hip and/or groin problem. The questions should be answered considering your hip and/or groin function during the **past week**.This information will help us keep track of how you feel, and how well you are able to do your usual activities.

Answer **every** question by ticking the appropriate box. Tick only one box for each question. If a question does not pertain to you or you have not experienced it in the past week please make your "best guess" as to which response would be the most accurate.

Symptoms

These questions should be answered considering your hip and/or groin **symptoms** and difficulties during the **past week**.

S1 Do you feel discomfort in your hip and/or groin?

Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Always ☐

S2 Do you hear clicking or any other type of noise from your hip and/or groin?

Never ☐ Rarely ☐ Sometimes ☐ Often ☐ All the time ☐

S3 Do you have difficulties stretching your legs far out to the side?

None ☐ Mild ☐ Moderate ☐ Severe ☐ Extreme ☐

S4 Do you have difficulties taking full strides when you walk?

None ☐ Mild ☐ Moderate ☐ Severe ☐ Extreme ☐

S5 Do you experience sudden twinging/stabbing sensations in your hip and/or groin

Stiffness

The following questions concern the amount of stiffness you have experienced during the **past week** in your hip and/or groin. Stiffness is a sensation of restriction or slowness in the ease with which you move your hip and/or groin.

S6 How severe is your hip and/or groin stiffness after first awakening in the morning?

None ☐ Mild ☐ Moderate ☐ Severe ☐ Extreme ☐

S7 How severe is your hip and/or groin stiffness after sitting, lying or resting **later in the day**?

None ☐ Mild ☐ Moderate ☐ Severe ☐ Extreme ☐

Pain

P1 How often is your hip and/or groin painful?

Never ☐ Monthly ☐ Weekly ☐ Daily ☐ Always ☐

P2 How often do you have pain in areas other than your hip and/or groin that you think may be related to your hip and/or groin problem?

The following questions concern the amount of pain you have experienced during the **past week** in your hip and/or groin. **What amount of hip and/or groin pain have you experienced during the following activities?**

P3 Straightening your hip fully

None ☐ Mild ☐ Moderate ☐ Severe ☐ Extreme ☐

P4 Bending your hip fully

None ☐ Mild ☐ Moderate ☐ Severe ☐ Extreme ☐

P5 Walking up or down stairs

None ☐ Mild ☐ Moderate ☐ Severe ☐ Extreme ☐

P6 At night while in bed (pain that disturbs your sleep)

P7 Sitting or lying

None ☐ Mild ☐ Moderate ☐ Severe ☐ Extreme ☐

The following questions concern the amount of pain you have experienced during the **past week** in your hip and/or groin. **What amount of hip and/or groin pain have you experienced during the following activities?**

P8 Standing upright

None	Mil	Moderate	Severe	Extrem
☐	☐	☐	☐	☐

P9 Walking on a hard surface (asphalt, concrete, etc.)

None	Mil	Moderate	Severe	Extrem
☐	☐	☐	☐	☐

P10 Walking on an uneven surface

None	Mil	Moderate	Severe	Extrem
☐	☐	☐	☐	☐

Physical function, daily living

The following questions concern your physical function. **For each of the following activities please indicate the degree of difficulty you have experienced in the past week due to your hip and/or groin problem.**

A1 Walking up stairs

None	Mild	Moderate	Severe	Extrem
☐	☐	☐	☐	☐

A2 Bending down, e.g. to pick something up from the floor

None	Mil	Moderate	Severe	Extrem
☐	☐	☐	☐	☐

A3 Getting in/out of car

None	Mild	Moderate	Severe	Extrem
☐	☐	☐	☐	☐

A4 Lying in bed (turning over or maintaining the same hip position for a long time)

None	Mil	Moderate	Severe	Extrem
☐	☐	☐	☐	☐

A5 Heavy domestic duties (scrubbing floors, vacuuming, moving heavy boxes etc)

Function, sports and recreational activities

The following questions concern your physical function when participating in higher-level activities. Answer **every** question by ticking the appropriate box. If a question does not pertain to you or you have not experienced it in the past week please make your "best guess" as to which response would be the most accurate. **The questions should be answered considering what degree of difficulty you have experienced during the following activities in the past week due to problems with your hip and/or groin.**

SP1 Squatting

None	Mil	Moderate	Severe	Extrem
☐	☐	☐	☐	☐

SP2 Running

None	Mil	Moderate	Severe	Extrem
☐	☐	☐	☐	☐

SP3 Twisting/pivoting on a weight bearing leg

None	Mil	Moderate	Severe	Extrem
☐	☐	☐	☐	☐

SP4 Walking on an uneven surface

None	Mil	Moderate	Severe	Extrem
☐	☐	☐	☐	☐

SP5 Running as fast as you can

None	Mil	Moderate	Severe	Extrem
☐	☐	☐	☐	☐

SP6 Bringing the leg forcefully forward and/or out to the side, such as in kicking, skating etc.

None	Mil	Moderate	Severe	Extrem
☐	☐	☐	☐	☐

SP7 Sudden explosive movements that involve quick footwork, such as accelerations, decelerations, change of directions etc.

SP8 Situations where the leg is stretched into an outer position

(such as when the leg is placed as far away from the body as possible)

Participation in physical activities

The following questions are about your ability to participate in your preferred physical activities. Physical activities include sporting activities as well as all other forms of activity where you become slightly out of breath. **When you answer these questions consider to what degree your ability to participate in physical activities during the past week has been affected by your hip and/or groin problem.**

PA1 Are you able to participate in your preferred physical activities for as long as you would like?

Always ☐ Ofte ☐ Sometimes ☐ Rarely ☐ Neve ☐

PA2 Are you able to participate in your preferred physical activities at your normal performance level?

Quality of Life

Q1 How often are you aware of your hip and/or groin problem?

Never ☐ Monthly ☐ Weekly ☐ Daily ☐ Constantly ☐

Q2 Have you modified your life style to avoid activities potentially damaging to your hip and/or groin?

Q3 In general, how much difficulty do you have with your hip and/or groin?

None ☐ Mil ☐ Moderate ☐ Severe ☐ Extrem ☐

Q4 Does your hip and/or groin problem affect your mood in a negative way?

Not at all ☐ Rarely ☐ Sometimes ☐ Often ☐ All the time ☐

Q5 Do you feel restricted due to your hip and/or groin problem?

Not at all ☐ Rarely ☐ Sometimes ☐ Often ☐ All the time ☐

Thank you very much for completing all the questions in this questionnaire.