Injuries and Injury Prevention in Male and Female Gaelic Games

Calvin Teahan (B.Sc.)

A thesis submitted for the award of Doctor of Philosophy

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Supervisors: Dr. Enda Whyte and Dr. Siobhán O'Connor

School of Health and Human Performance
Dublin City University

Declaration

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of Doctor of Philosophy is entirely my own work, and that I have exercised reasonable care to ensure that the work is original, and does not to the best of my knowledge breach any law of copyright, and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

Signed: Calvin Teahan Student ID: 15512847 Date: 28/08/2023

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This thesis is dedicated to the memory of my dad Denis.

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List of Abbreviations

ACL: Anterior Cruciate Ligament
AFL: Australian Football League
AU: Arbitrary Units
BMI: Body Mass Index
BW: Body Weight
CA: Camogie Association
CI: Confidence Interval
CIPP: Camogie Injury Prevention Program
cm: Centimetre
CMJ: Counter Movement Jump
EMG: Electromyograph
GAA: Gaelic Athletic Association
GG: Gaelic games
GPS: Global Positioning System
HIS: Hamstring Strain Injury
HSR: High Speed Running
ICC: Intraclass Correlation Coefficient
IP: Incidence Proportion
IPEP: Injury Prevention Exercise Programme
IR: Injury Rate
IRR: Incidence Rate Ratio
kg: Kilogram
km/h: Kilometres per hour
LESS: Landing Error Scoring System
LGFA: Ladies Gaelic Football Association
LOE: Level of Evidence
m: Meters
Min: Minutes
N: Newtons
N/kg: Newtons per kilogram
NCAA: National College Athletic Association
NHE: Nordic Hamstring Exercise
OR: Odds Ratio
RDL: Romanian Deadlift
RE-AIM SSM: Reach Efficacy Adoption Implementation Maintenance Sports Setting Matrix
ROM: Range of Motion
RPE: Rate of Perceived Effort
RR: Risk Ratio
RSImod: Modified Reactive Strength Index
SD: Standard Deviation
Sec: Seconds
SMD: Standardised Mean Difference
TD: Total distance
TL: Training load
TRIPP: Translating Research into Injury Prevention Practice

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Abstract

Title: Injuries and Injury Prevention in Male and Female Gaelic Games.
Author: Calvin Teahan

Background: Understanding the epidemiology of injury and risk factors for injury are critical for injury prevention strategies. It is unknown if risk factors for particular injuries apply to Gaelic games (GG). Effective injury prevention exercise programmes (IPEP) have been developed, but their use is anecdotally low.

Aims: Investigate injury epidemiology in GG, focusing on injury burden. Assess a screening protocol to identify GG players at risk of hamstring injury (HSI). Investigate GG players' and coaches' awareness, use and attitudes towards IPEP.
Methods: Injury epidemiology was prospectively captured in collegiate GG players. A screening protocol was designed based on the literature and epidemiological study. An online questionnaire was developed and distributed to adult players and coaches investigating current injury prevention practices.
Results: Injury rates were high in all GG codes. HSI were the most common in Gaelic football, and calf injuries in hurling/Camogie. However, HSI had the largest burden of injury in all GG codes. Study 2. Preseason screening identified previous HSI, increased age, and increased height on the countermovement jump as risk factors for HSI. Using GPS, injured players covered more significant high-speed running distance, sprint distance and sprints in speed zone 5 on the week of their injury than uninjured players. Weekly testing of knee-to-wall, eccentric hamstring strength and countermovement jump did not differ. Study 3. Awareness and use of IPEP was low amongst GG players and coaches. However, both had a positive attitude to injury prevention. Many coaches currently alter/create their own IPEP. Players lack confidence in their coach's ability to deliver an IPEP.
Conclusion: GG players are susceptible to lower limb injuries. Limiting spikes in high-speed running distances may mitigate HSI risk. The positive attitude to injury prevention is promising. However, organisations need to incorporate injury prevention training in coaching education.

Chapter 1 Introduction

1.1 Background and Rationale for Research

Gaelic football, hurling and Camogie (female version of hurling) are amateur native Irish sports (Fox et al., 2014) with growing interest abroad (Murphy et al., 2014), and are the most popular sports in Ireland in terms of participation (TSSI, 2020). Gaelic games (the collective term) uniqueness stems from their deeply rooted cultural significance as they are community-based sports played in many age groups from as young as three years of age (ESRI, 2018), consisting of a maximum of 15 players depending on the age group. Gaelic games are field-based sports, played on a pitch with greater dimensions (130–145 m long, 80–90 m wide) than both soccer and rugby (Boyle et al., 2022; Reilly and Collins, 2008). The emphasis on amateurism further set Gaelic games apart, prioritizing the love of sport and community over financial gain. The aim of the game is to outscore the opposition, which is achieved by either putting the ball over the crossbar for 1 point or scoring a goal by putting the ball in the net and under the crossbar for 3 points (Wilson et al., 2007). Gaelic games players engage in body contact, jumping, accelerations, decelerations, change of direction, hand passing, jumping, and catching the sliotar/ball above the head, all while under pressure from an opponent (Murphy et al., 2010; Malone et al., 2019). Unfortunately, injuries can happen in Gaelic games because of the sports' inherent demands. However, by implementing injury prevention strategies and programmes, the frequency and severity of many injuries may be decreased (Meeuwisse et al., 2007). Therefore, injury prevention is essential, particularly in community-level sports because sports injuries can cause players to drop out of the sports (Lunn et al., 2013).

Finch (2006) proposed a six-step framework called the Translating Research Into Injury Prevention Practice framework (TRIPP) to translate injury prevention programmes into practice. The first step in the TRIPP framework is to establish the extent of the problem through injury surveillance. There is a lack of epidemiological studies in Gaelic games, with most research focusing on elite male Gaelic footballers and it is crucial that injury prevention efforts are sport specific. Injury rates vary considerably across different sports and also the different codes of Gaelic games and levels. Therefore, the first study aims to investigate the non-elite Gaelic games population in all codes, as there is a paucity of research on this population which makes up the majority of players. However, one thing that remains consistent throughout the current literature is that match injury rates are much higher than training injury rates which may be attributed to the competitive nature of the sports. Across all four codes of Gaelic games, injuries predominantly occur to the lower limb, and injuries to this region range from 46.9-79.3% of all injuries (Roe et al., 2018; O'Connor et al., 2020; Blake et al., 2014; Buckley and Blake, 2018). The hamstring muscle was the most frequently injured body part in 7 out of 9 prospective adult studies in Gaelic games and can be as high as 31% of all injuries (Roe et al., 2018; O'Connor et al., 2016; Murphy et al., 2012; Wilson et al., 2007; Newell et al., 2006; O'Connor et al., 2020; Blake et al., 2014; Murphy et al., 2010; Buckley and Blake, 2018). Previous epidemiological research in Gaelic games has primarily focused on injury rates and severity in isolation. It has been argued that the practice of reporting injury rates and severity in isolation by epidemiologists has to change, and there is a need to consider injury burden (Bahr et al., 2017). However, only three studies have reported injury burden, all of which have been in Gaelic football (O'Connor et al., 2020; Roe et al., 2018; O'Connor et al., 2016). Not only do hamstring injuries have a high prevalence of injury, but they also have a large burden of injury (Roe et al., 2018; O'Connor et al., 2016; O'Connor et al., 2020). Therefore, screening protocols must be developed to identify risk factors for hamstring injuries in Gaelic games.

The next stage of the TRIPP framework is to understand the aetiology of injuries. This involves understanding the mechanisms of injury and also the risk factors for injury. Non-contact injuries occur 50% of the time in Gaelic games, and sprinting was the mechanism of injury for almost a fifth of all injuries (O'Connor et al., 2016; O'Connor et al., 2016; Murphy et al., 2012; Wilson et al., 2007; O'Connor et al., 2020; Blake et al., 2014; Buckley and Blake, 2018). This may be due to the high prevalence of hamstring injuries which predominantly occur during sprinting, specifically during the terminal swing phase when the muscle is lengthened and working eccentrically to slow down the swinging shank (Danielsson et al., 2020). Injury risk factors can be described as modifiable and non-modifiable risk factors. Modifiable risk factors allow for developing a preventative intervention to change a player's risk (Bahr and Holme, 2003). Non-modifiable risk factors can enable the identification of players in the greatest need for preventative interventions to reduce their risk of injury. A single risk factor is rarely solely responsible for an injury, and risk factors interact with each other and change with each exposure (Meeuwisse et al., 2007). Therefore, determining the risk profile of a player may provide information about the risk of an injury occurring (Bittencourt et al., 2016). Some non-modifiable risk factors, such as age, a history of previous injury, and playing position, are well-established as strongly associated with hamstring injuries (Green et al., 2020). Studies that have investigated modifiable risk factors provide more conflicting associations with hamstring injury findings with some studies reporting an association and others not for the same modifiable risk factors (Green et al., 2020) and therefore, may need to be tested more frequently due to seasonal outcome variations. Similarly, most risk factor studies have been completed on athletes in elite sports and haven't been tested in community-level sport. Eccentric hamstring strength measured using the Nordic hamstring test has conflicting associations with hamstring injuries. Some studies have found that decreased absolute eccentric strength (Timmins et al., 2016; Opar et al., 2015) and greater between limb imbalances (Bourne et al., 2015) increased the risk of hamstring injuries. However, many studies have found no association. Increased weekly high-speed running exposure and rapid changes in high-speed running exposure were associated with hamstring injuries in Australian rules football (AFL) (Ruddy et al., 2018; Duhig et al., 2016). Although some studies have shown an association between high-speed running exposure and the risk of hamstring injuries, there has been no research in the Gaelic games context, and previous research has shown that results from one sport don't always translate to the same finding in another sport (Lee Dow et al., 2021). Therefore, it is critical that risk factors for hamstring injuries are investigated in a Gaelic games cohort. This may inform future interventions which may reduce the number and burden of hamstring injuries. Although the first study in this research project was completed on a non-elite cohort, the second study was carried out during COVID-19 and had to be investigated on elite-level Gaelic footballers due to national restrictions at the time of testing.

The third and fourth stages of the TRIPP framework are to develop and access the preventative intervention under ideal conditions (Finch, 2006). Several injury prevention programmes have already been developed to reduce injuries in Gaelic games, including the GAA 15, the Activate GAA warm up and the Camogie Injury Prevention Program. Previous research has found that the GAA 15 can decrease injury rates (Schlingermann et al., 2018; Kelly and Lodge, 2018) while also improving neuromuscular performance (Schlingermann et al., 2018; O'Malley et al., 2017) along with the Activate GAA warm up (O'Connor et al., 2022). To succeed in the real world, injury prevention exercise programmes must first be accepted, adopted and used as designed by stakeholders (Finch, 2006). Yet, awareness of and use of injury prevention programmes amongst the Gaelic games community is relatively poor (Reilly and Kipps, 2017; O'Connor et al., 2020). However, one study had very low participant numbers, and the other focused solely on Camogie coaches and players. Therefore further research is needed investigating Gaelic games players' and coaches' awareness and use of the already developed effective injury prevention exercise programmes across all codes at both an elite and non-elite level. Similarly, the injury prevention context is vital and proposed implementation approaches are more likely to be practically applied and sustained if players, coaches, and club administrators are involved in the development and implementation planning. Closing the gap between research-driven (top-down) and community-driven (bottom-up) injury prevention programme implementation is a priority to lead to real change in terms of injury rates and burden in Gaelic games (Donaldson et al., 2017). Therefore, understanding the attitude of stakeholders towards injury prevention exercise programmes and their perceived barriers and facilitators towards the successful implementation of an intervention is critical to their success. This information is vital in all codes across all levels of play, as there can be a considerable discrepancy in access to resources in Gaelic games.

The approach to this thesis is primarily an objectivist epistemological approach where quantitative methods are mainly employed (Hausken-Sutter et al., 2022; Hulme and Finch, 2016). The objectivist perspective strongly emphasises the logical development of ideas based on discrete empirical facts (Biggs and Büchler, 2007). Following the TRIPP framework as a guideline to the research, the first and second studies aim to quantify the extent of the injury problem through epidemiological methods to determine the true nature of the injury and identify factors related to injury aetiology (Hausken-Sutter et al., 2021). When using this strategy, the final explanation for the association between a discrete group of variables chosen and examined is frequently reductionist, although injury and injury risk factors are multifactorial. The third and fourth studies are primarily objectivist as they quantify the awareness and use of injury prevention exercise programmes in Gaelic games in all codes and levels. However, this objectivist approach alone masks much of the problem's complexity, and to deal with this complexity more effectively, studies 3 and 4 take a more pragmatic (mixed method) approach (Hulme and Finch, 2016), as there is both objectivism and constructivism, which investigates the complexity rather than using a single approach (Hausken-Sutter et al. 2022). This complexity is explored as the attitudes towards injury prevention, barriers and facilitators are investigated in a diverse range of players. However, these studies do not take a qualitative approach.

Aims and objectives of the thesis

The overall aim of this research project was to understand the injuries and the risk factors for the most common injuries while describing the context for injury prevention exercise programme implementation in Gaelic games. This was achieved with a multifactorial approach. The project investigated the epidemiology of injury across all codes of Gaelic games, focusing on the burden of injury (Chapter 3). Hamstring injuries are a common injury in Gaelic games; therefore, the project aimed to investigate the aetiological factors of a hamstring injury at preseason and weekly using risk factors established in other field-based sports (Chapter 4). In addition, we aimed to explore different stakeholders in Gaelic games' attitudes, awareness and use of already developed injury prevention exercise programmes (Chapters 5 and 6).

The specific aims of each of the studies are:

1) To determine the incidence and burden of injury and establish the mechanisms of injury in male and female Gaelic games players (Chapter 3)
2) To investigate risk factors for hamstring injuries in Gaelic games players at preseason (Chapter 4)
3) To investigate the differences in high-speed running exposure and performance tests between injured and uninjured players, and injured players at different times across the season (Chapter 4)
4) To determine the awareness of and use of injury prevention exercise programmes in Gaelic games players' and their attitudes towards injury prevention (Chapter 5)
5) To determine the awareness of and use of injury prevention exercise programmes in Gaelic games coaches' and their attitudes towards injury prevention (Chapter 6)

Chapter 2 Literature Review

2.1 Description of Gaelic Games

The male sports of Gaelic games (Gaelic football and hurling) are governed by the Gaelic Athletic Association (GAA), whereas the female sports of Ladies Gaelic football and Camogie are governed by the Ladies Gaelic Football Association (LGFA) and Camogie Association (CA) respectively. Gaelic games are community sports and are played across many levels, both elite and non-elite, and players can play across multiple levels and codes at any one time (Sullivan et al., 2020). The elite level of Gaelic games is played in inter-county competitions when teams comprise the top club players from each county (Malone et al., 2017). Gaelic games players play for their clubs, schools and colleges at a non-elite level. Gaelic games are the most popular sports in Ireland (TSSI, 2020) and are based at the heart of the community, with clubs in most parishes across the country (Reilly and Collins, 2008). They are played on a grass field with a length up to a maximum of 145m, a width of 90m and “H” style goalposts at either end (Watson, 1996), making it up to 40% larger than a soccer pitch (Florida-James and Reilly, 1995). The crossbar is 2.5 meters from the ground, with two upright posts 6.5 meters apart, standing at least 7 meters tall (Watson, 1996). All teams consist of 15 players with one goalkeeper, two defending lines of three known as backs, two midfielders and two attacking lines of three known as forwards (Young et al., 2019; Reilly and Collins, 2008). The purpose of the game is to outscore the opposition, and it is accomplished by scoring; putting the ball over the crossbar equals 1 point or scoring a goal which counts for 3 points by putting the ball in the net and under the crossbar (Wilson et al., 2007). While considered an amateur sport, some players at the elite level are believed to have the commitment, effort, and attitude of players at the professional sports level (Cromwell et al., 2000). Players may attend up to 3 pitch sessions a week as well as strength and conditioning sessions while trying to balance this commitment with their professional and personal life (Beasley, 2015; O’Grady et al., 2022). As Gaelic games are amateur in nature, players are generally in full-time employment and/or education and frequently lack adequate time to recover (Lane, 2015). Typical non-elite matches last 60 minutes, but elite matches are played over 70 minutes for males and 60 minutes for females (Mangan et al., 2022; Boyle et al., 2022; Malone et al., 2022). At the elite level, the competitive season can last up to 7 months, from January to the end of July consisting of a league from January to April followed by a championship knockout series until July with crowds of over 82,000 in attendance at finals (Malone et al., 2016).

2.1.1 Gaelic Football

Gaelic football resembles Australian Football and is a mixture of both soccer and rugby with the ball being round like a soccer ball (O'Connor et al., 2016; Reilly and Doran, 2001). The ball may be played in any direction by players using either their hands or feet while carrying it in their hand (Mangan et al., 2022). Throwing the ball is not authorised. Players must bounce the ball or solo the ball (an action where the ball is dropped from the hand to the foot and kicked back up again) every four steps while in possession of the ball (Mangan et al., 2022). There are slight differences between male Gaelic football and Ladies Gaelic football, such as shoulder-to-shoulder charges are not permitted in the female game, and females can pick the ball up from the ground. Their goalkeeper can take kick-outs from their hand, but no attacking or kick-out mark is permitted as is allowed in the male game (Kelly et al., 2022). Both are contact sports requiring competitiveness, strength, speed, and agility, with activities such as kicking, soloing, bouncing, blocking, hand passing, catching, sprinting, and jumping, turning required (Reilly and Doran, 2001). The physiological demands of the game see a player require moderate continuous aerobic capacity with short sharp anaerobic bouts coming in the form of intermittent changes of pace and direction (Florida-James and Reilly, 1995; Cullen et al., 2017). Gaelic footballers will cover between 18,417 ± 1,276 m and 22,369± 2,300 m across a training week (Malone et al., 2021) and can spend between 11.8-17.6% at high-speed running, which is defined as greater than 17 km/h (McGahan et al., 2018). However, differences exist between the divisional status (McGahan et al., 2021), level (Mangan et al., 2020), gender (Malone et al., 2022), and even positions but similarities exist, such as the middle three lines completing the greatest amount of total distance and high-speed running distance and a drop off in the final three quarters (Table 2.1). Further research is still needed, particularly in Ladies Gaelic football and the sub-elite players, as understanding the demands of the game can inform coaches to put in place strategies to increase performance and reduce the risk of injury.

2.1.2 Hurling/Camogie

Hurling and Camogie are highly skilled, stick and ball, field-based sports resembling field hockey and lacrosse (Young et al., 2019; Collins et al., 2018). The stick (made of ash) and ball are termed a hurley and sliotar, respectively (Malone et al., 2020), and it is one of the fastest field game sports in the world, with the sliotar reaching speeds of up to 160 km/h (Murphy et al., 2010). The sliotar is made up of padded cork filling on the inside covered by a leather outer layer (Reilly and Collins, 2008), weighing between 110-120 grams and has a diameter of up to 72 mm (Murphy et al., 2010). Hurling and Camogie are very similar except for minor rule changes, such as a side-line cut is worth two points in Camogie but one in hurling (Camogie.ie, 2021). Only one person may stand on the goal line for a penalty in hurling, but three can for Camogie and more relevant to injury, shouldering is not permitted in Camogie (Camogie.ie, 2021). Hurling is believed to predate all football codes and is considered the world's oldest stick and ball game (Reilly and Collins, 2008). Similar to Gaelic football, hurling and Camogie place various demands on the aerobic and anaerobic systems (Duggan et al., 2020). However, hurling potentially requires less sprint endurance because the sliotar can travel over 65 meters in any one play (McIntyre, 2005). The running demand of hurling and Camogie are described in Table 2.1. Similar to Gaelic football, elite hurlers spend 10% of their total distance at high-speed running (Young et al., 2018) and complete a mean of 22.2 sprints per game (a sprint being greater than 22 km/h) while reaching speeds of 29.9km/h (Young et al., 2019). Like hurlers and Gaelic footballers, Camogie players spend 9% of their total distance at high-speed running. However, Camogie players completed fewer sprints (12) per game and reached less max speed (24.9 km/h) (Young et al., 2021). Hurling and Camogie players engage in body contact, jumping, accelerations, decelerations, change of direction, balancing or bouncing the sliotar on the hurley while running, hand passing, jumping, and catching the sliotar above the head, and defending by using the hurley to block, flick or hook the sliotar from the opponent (Buckley and Blake, 2018; Murphy et al., 2010; Malone et al., 2019).

Table 2. 1. Match Play Running Demands of Gaelic football, Ladies Gaelic football, Hurling and Camogie players measured using GPS.

Author	**Participants**	**Total distance (m)**	**Relative distance (m/min)**	**High-Speed running distance (m)**	**Sprint distance (m)**	**Maximum speed (km/h)**
Gaelic football						
McGahan et al., 2021	Elite Div 1 n=23 Div 3 n=24	-	-	Div 1 - 1145±436 Div 3 - 1358±462	-	-
Mooney et al., 2021	Elite U20 n=29	6979±1235	104±18	129±417	477±194	30.6±1.4
Daly et al., 2020	SC n=41	7134.7±1194.9	-	-	742.0±229.9	29.2±2.2
Mangan et al., 2020	SC n=37 IC n=31	SC - 7270±1216 IC - 7021±1124	SC - 111.6±17.7 IC - 106.7±16.1	-	-	SC - 29.4±1.4 IC - 28.8±1.6
Malone et al., 2017	Elite Div 1&2 n=50	8889±1448	-	1596±594	445±69	30.3±1.2
Malone et al., 2016	Elite n=50	8160±1482	116±21	1731±659	445±269	30.3±1.8
Ladies Gaelic football						
Malone et al., 2022	Elite n=33	7319±1021	116±9	1547±432	630±287	25.8±1.5
Hurling						
Egan et al., 2021	Elite n=50	NL - 7808±1234 C - 8172±1003	NL - 106±17 C - 110±14	NL - 1215±369 C - 1253±258	NL - 362±127 C - 406±86	NL - 30.0±1.7 C - 31.3±1.2
Young et al., 2020	Elite U17 n=76	6483±1145	108±19	583±215	272±77	28.1±2.9
Young et al., 2019	Elite n=36	7506±1364	107±20	1169±260	350±93	29.1±2.1
Collins et al., 2018	Elite n=94	7617±1219	109±17	1134±358	319±129	29.6±2.2
Young et al., 2018	Elite U21 n=95	6688±942	112±16	661±203	274±111	29.1±1.9
Young et al., 2018	Elite n=24 Non-elite n=24	-	Elite 118±9 Non-elite 93±16	-	-	-
Camogie						
Young et al., 2021	Elite n=36	5881±906	98±15	546±259	183±130	-

Div: division; n: sample size; m: metres; m/min: metres per minute; km/h: kilometres per hour; SC: senior club; IC: intermediate club; NL: national league; C: championship.

2.2 TRIPP Framework

2.2.1 The Development of the TRIPP Framework

There are many health benefits associated with physical activity and sports participation, such as; the promotion of healthy growth and development, reduced risk of cardiovascular disease and a variety of other chronic diseases, many cancers, obesity, bone and joint diseases and depression (Warburton et al., 2006; Emery and Pasanen, 2019). Sport and physical activity participation can also have a positive effect on one's mental health (Rodriguez-Ayllon et al., 2019). Decreased physical activity involvement will negatively impact future health (Curtis et al., 2017; Lee et al., 2012). However, with the benefits of sports participation comes the apparent danger to health in the form of sports injuries (van Mechelen et al., 1992). Sports participation raises the risk of sports injuries, which account for most injuries in children and significantly impact the adult population (Emery and Pasanen, 2019). Van Mechelen et al. (1992) identified the need for injury prevention to combat the extent of the sports injury problem and created the "sequence of prevention" model (Figure 2.1).

The sequence of prevention is a four-stage injury prevention model. It was the first of its kind and was an important tool to guide sports injury prevention research from the early nineties to the early two thousand (Finch, 2006). The four-stage model outlines the direction of evidence needed to build a base for preventing sports injuries and their causative factors. However, it doesn't describe the direction required for research that leads to direct injury prevention (Finch, 2006). The ability of the sequence of prevention to describe the behavioural elements that influence the adoption and uptake of intervention is limited. Therefore, Finch suggested that for injury prevention to be successful, sports injury prevention strategies must be approved, implemented, and followed by the players, coaches and sports organisations they are intended for. If not, preventative efforts will fail (Finch, 2006).

One of the critical difficulties noted with the sequence of prevention was the need for adequate detailed information to examine the elements that directly lead to injury prevention (Finch, 2006). Further shortcomings include an absence of investigating implementation challenges that arise after injury prevention protocol/strategy development and testing and a dearth of understanding of the causes and impacts of sport safety behaviours (Finch, 2006). The lack of concern and understanding about preventative techniques' adoption and compliance might be key to the negative or minor impacts seen in earlier research. For this reason, Finch built on the sequence of prevention by introducing a new 6-stage framework: Translating Research into Injury Prevention Practice (TRIPP) model (Figure 2.1) (Finch, 2006). The core element of this extension of the sequence of prevention was that evaluating a preventive strategy's effectiveness in controlled environments wouldn't be enough to avoid damage in the real world; instead, preventative interventions would only have an impact if they were widely adopted and maintained (Hanson et al., 2014).

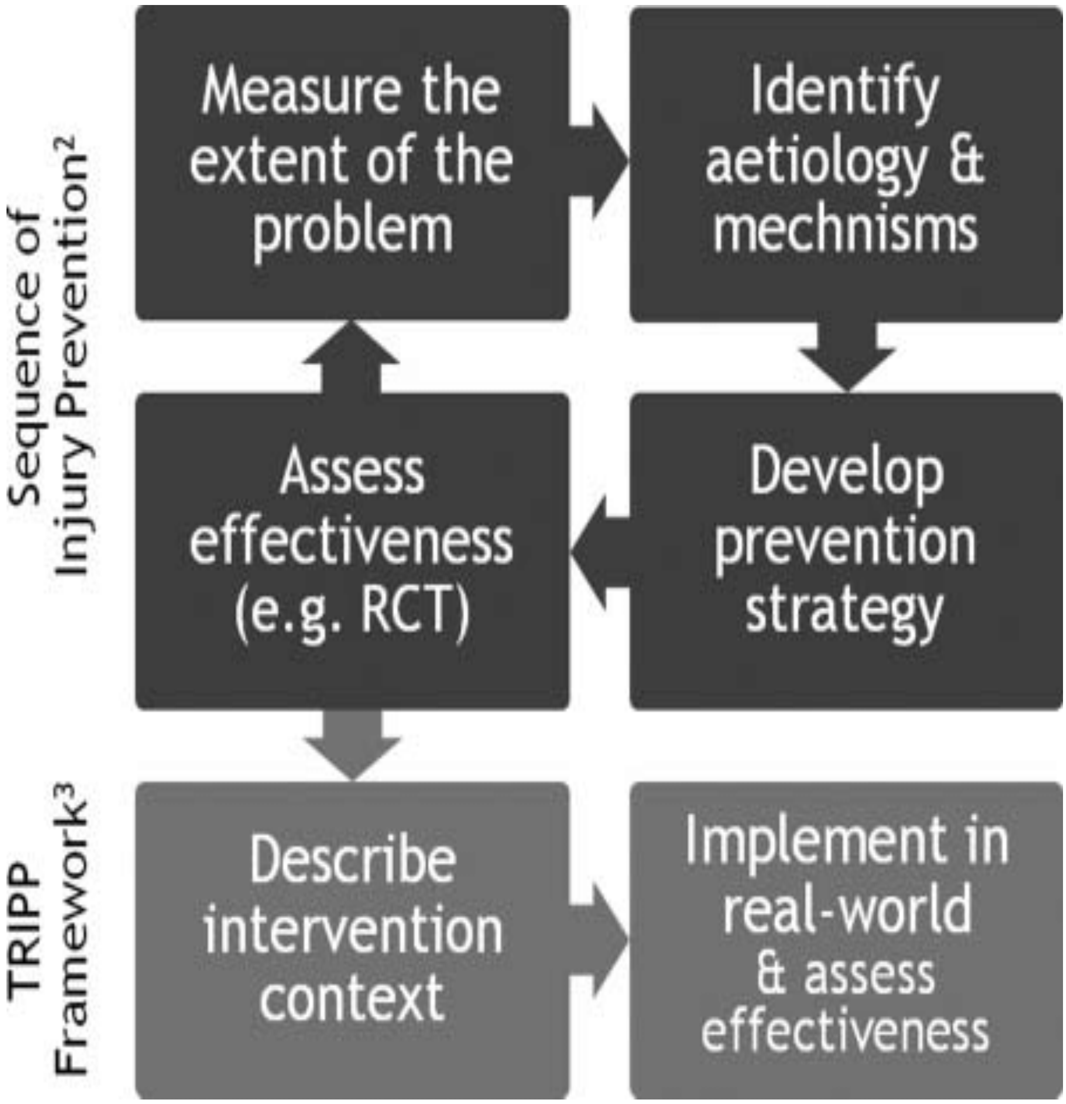

Figure 2. 1. A systematic approach to sports injury prevention. The original 4-step "sequence of prevention (van Mechelen et al., 1992), which was later expanded to the TRIPP framework (Finch, 2006).

2.2.2 TRIPP Framework Description

TRIPP Stage 1. *Injury surveillance*

The first stage of the TRIPP framework is similar to the sequence of prevention (Finch, 2006; van Mechelen et al., 1992). The main goal in stage 1 is to establish the extent of the problem through injury surveillance. Injury surveillance data of high quality is critical for informing all other phases of the TRIPP framework. Injury surveillance activities can only help if valid and reliable procedures are established and accepted to allow for routine, ongoing sports injury monitoring and reporting (Finch, 2006).

TRIPP Stage 2. *Establish aetiology and mechanisms of injury*

This stage gathers information to understand the aetiology of, the risk factors and mechanisms for injuries. Understanding the interaction between the risk factors and the mechanism of injury is vital. The information gathered at this stage is critical for prevention as it can provide crucial insights into which specific risk factors should be altered or targeted to mitigate injury risk (Finch, 2006). Identifying the risk factors is important, but by itself isn't enough. Therefore, the exact mechanisms of injury must be identified, which can be achieved through epidemiological studies (van Mechelen et al., 1992). The best way to capture this data is to use prospective cohort studies, where the uninjured participants are followed over time until an injury occurs and the exact mechanisms are recorded (Finch, 2006). However, the majority of sports injuries have a multifaceted cause, making it difficult to pinpoint the exact mechanisms and risk factors (Van Tiggelen et al., 2008).

TRIPP Stage 3. *Develop the preventative measures*

After the extent of the injury problem has been determined and predisposing factors and mechanisms linked to injury have been discovered, it is then possible to start developing preventative methods to lower injury rates. Potential solutions to the problem are identified in this stage. They should be guided by the epidemiological information gathered from stage 1 and the aetiology of these injuries identified in stage 2 of the TRIPP framework. Until this step, the sequence of prevention models and the TRIPP framework have been almost identical. In stage 3, van Mechelen et al. (1992) develops and introduces the prevention strategy. Preventative interventions are frequently advised based on anecdotal experience or established practice, with little consideration given to why they may or may not be effective. However, it suggested that theoretical foundations and context awareness are required to understand the injury processes from TRIPP Stages 1 and 2 and develop countermeasures. Laboratory-based studies or simulations may achieve this to test the interventions (Finch, 2006).

TRIPP Stage 4. *Ideal conditions/scientific evaluation*

The TRIPP Stage 4 refers to the evaluation of intervention efficacy and is essentially an "ideal conditions" assessment of the preventative measures developed from the TRIPP Stage 3 evaluation. Much of the "ideal conditions" are carried out in a lab or a small focus group. However, Finch (2006) suggests that randomised control trials are considered to be under "ideal conditions" as preventative interventions take place under the guidance of a scientific researcher with resources, infrastructure and staffing that would not readily be available in real-world conditions or after the intervention study is concluded. Studies with negative findings don't always make it into the literature, but they should be encouraged, especially studies with implementation problems.

TRIPP Stage 5. *Describe intervention context to inform implementation strategies*

The TRIPP Stage 5 is best described as the stage of building and comprehending the implementation context. It is used to comprehend how efficacy research findings may be transferred effectively into actions that can be executed in the real-world setting of on-field sports behaviour and delivery. This stage creates an understanding of the current safety behaviours being implemented and whether they need to be altered. Players may adopt safety behaviours, the aetiological and efficacy studies suggest, but they may not be effective for some reason in specific contexts. Alternatively, there may be no implementation of safety strategies, and it is critical to understand why. Therefore, it is equally important to understand barriers and facilitators to implementation and players' and coaches' attitudes to injury prevention strategies. Understanding the culture of the sport with regards to safety and injury is also essential, as is staffing, resources, finances, infrastructure, support and other equipment available. For successful implementation to occur, the intervention context needs to be understood, i.e. who the intervention will be adopted by and under what circumstances. Determining how feasible the developed interventions will ultimately be utilised is crucial before devising preventative strategies for widespread use. "By whom?" and "under what circumstances?" are critical questions that need to be answered (Finch, 2006). However, research on this step investigating context, a key implementation factor, needs to be added to (Ross et al., 2021).

TRIPP Stage 6. *Evaluate effectiveness of preventative measures in implementation context*

The last step of the loop, TRIPP Stage 6, includes applying the intervention in a real-world setting and assessing its effectiveness. This stage involves evaluating the scientifically proven intervention identified in TRIPP stage 4 when used in the real-world environment of player behaviour and player culture after considering the cues for successful implementation identified in TRIPP stage 5.

2.2.3 Summary

The TRIPP framework outlines the actions researchers should take to address sports injuries by developing and implementing preventative measures. The TRIPP framework includes injury surveillance followed by epidemiological and aetiological research. This leads to the creation of an intervention guided by the implementation environment and stakeholders, first evaluated under ideal conditions followed by real-world settings. However, stage 6 is not the final stage of the TRIPP framework as it is an ongoing process with a return to stage 1 (Ross et al., 2021). Similarly, the TRIPP framework can move in several ways and is not strictly linear. It is essential that all implemented sports preventative measures must have a solid evidence foundation (Finch and Donaldson, 2010). However, it is also critical that they're effective and easy to implement in the "real world" because only those preventative measures that are implemented regularly will truly prevent injuries (Finch, 2006). Other significant factors that need to be kept in mind are if role models endorse them, if they are widely promoted and sport-specific, if they are a part of the sport's culture, and if stakeholders are aware of the advantages of using (Braham et al., 2004; Finch, 2006). While developing large-scale sports injury prevention efforts, researchers should consider the implementation context early by involving key stakeholders, highlighting that the TRIPP model is not linear. The TRIPP framework is superior to the sequence of prevention as it strives to get a better knowledge of the environment in which injury prevention is implemented and emphasises the necessity of understanding the attitudes and culture of all the stakeholders in sports injury prevention. This will ultimately increase the chance of intervention success in the real world. Thus the TRIPP framework offers sports injury prevention advocates and researchers an insightful road map.

2.3 Gaelic Games Epidemiology

2.3.1 Introduction

Establishing the extent of the problem and understanding the mechanisms of injury are critical for successful injury prevention. This is achieved by first implementing an injury surveillance system to record how common injuries are, what injuries are most common and the injury profile of the sport. This information will ultimately guide sports injury prevention activities and research into improving sports safety (Finch, 1997). Limited epidemiological research is available across the codes of Gaelic games (Section 2.3). Of all the four codes, male Gaelic football has the most research focus, with seven prospective studies looking at injuries in the game (Roe et al., 2018; O'Connor et al., 2016; O'Connor et al., 2016; Murphy et al., 2012; Blake et al., 2011; Wilson et al., 2007; Newell et al., 2006). Of these seven studies, 5 investigate injuries in elite Gaelic football, 1 in collegiate and 1 in adolescent Gaelic football. Four prospective studies investigate injuries in male hurling, of which three are in elite-level hurling (Blake et al., 2014; Blake et al., 2011; Murphy et al., 2010) and one on adolescent hurling (O'Connor et al., 2016). There are fewer studies investigating injuries in female Gaelic games. A total of three studies look at injuries in Ladies Gaelic football, two are retrospective (Brown et al., 2013; Crowley et al., 2011), and one prospective study examines injuries in female collegiate Gaelic footballers (O'Connor et al., 2020). There is only one prospective study on elite Camogie players (Buckley and Blake, 2018), with one retrospective questionnaire-based study examining self-reported worst injuries in elite and non-elite Camogie players (O'Connor et al. 2019). Prospective studies are recommended as they allow for the calculation of injury rates and are not associated with potential errors with recall and inaccuracy seen in retrospective studies (Fuller et al., 2006). For example, it has been found that only 61.4% could accurately recall the number of injuries, the body region, and the exact diagnosis after 12 months, and there is increased difficulty with the recall of minor injuries (Gabbe et al., 2003; Brooks and Fuller, 2006). Prospective studies can also more easily facilitate analysing the exact amount of exposure to injury risk (Hägglund et al., 2005).

Very few longitudinal studies look at injury in Gaelic games, with only four studies of a duration exceeding one year (O'Connor et al., 2020; Roe et al., 2018; Blake et al., 2014; Murphy et al., 2012). Emphasis should be placed on longitudinal studies rather than short-term projects for injury surveillance to get a true sense of injury rates, burden of injury and mechanisms of injury over a prolonged period. Most of the prospective research (6 studies) focuses on elite inter-county players, which make up less than 2% of all the teams in Ireland, as there are just 61 inter-county male teams and over 1616 affiliated clubs in Ireland (Kelly et al., 2018).

The existing epidemiological data informs us of the extent, burden, nature, and aetiology of injury in Gaelic games. Understanding each of these sections is critical to designing and implementing successful injury prevention in Gaelic games. There is a paucity of research on Gaelic games, particularly in hurling, Camogie, and Ladies Gaelic football. Further research is needed in these codes as epidemiology is the first and critical step for future injury prevention (Finch, 2006; van Mechelen et al., 1992). In this review of literature, a focus will be placed on prospective studies where possible. However, where there are limited or no prospective studies available in that specific population, retrospective studies will be included.

2.3.2 Injury definitions

There is no universal definition for sports injury (Nielsen et al., 2020). Differences in definitions arise due to the sport or context in which the statements were created. Injury definitions can include time loss, medical attention, reduced performance, or a combination of some or all. A broader definition may yield higher injury rates and incidence proportion (Nielsen et al., 2020; Bahr, 2009). A time loss definition is popular in the Gaelic games context (Table 2.2). Time loss has previously been described as the most important as it directly impacts a player's ability to participate in matches and training (Bahr, 2009). Narrow definitions are usually based on more objective criteria and are used to rule out less severe injuries. A time-loss injury may result in lower injuries being recorded.

Only 4 out of 15 epidemiological studies in Gaelic games included restricted performance as part of the definition, and only two included medical attention. Because not all health concerns impair a player's ability to compete or demand medical treatment, broader definitions (self-reported, symptom-based, or performance-based) will encompass a more comprehensive range of issues and may result in a higher proportion or rate of injuries (Bahr et al., 2020). However, obtaining detailed injury data with a broad definition may be time-consuming, need more subjective criteria, and collect a large number of injuries with little repercussions for players and coaches (e.g., cuts and bruises) (Nielsen et al., 2020). Physical complaints or functional restrictions usually develop gradually, and the player will most likely maintain participating in the presence of this overuse/chronic injury, especially in the early stages, where they may adjust their training until they seek medical attention (Clarsen et al., 2013). Physical complaints are quite prevalent in sport, but with nobody available to examine them, the majority will go unrecorded (Bahr, 2009), and this is particularly true in the amateur sports of Gaelic games. Recently the International Olympic Committee Consensus statement defined an injury as "tissue damage or other derangement of normal physical function due to participation in sports, resulting from rapid or repetitive transfer of kinetic energy" (Bahr et al., 2020). This definition is meant to be broad and inclusive (Bahr et al., 2020), which may give a greater understanding of injuries and illness within the sporting context. However, it may result in less meaningful data for players and coaches who may be more concerned about player availability, impacting success (Hägglund et al., 2013).

Table 2. 2. Author, Study type, Participants and Definition of Injury in Previous Gaelic games Research.

Author & Year	**Study Type**	**Level/Participants**	**Mean age**	**Definition of Injury**	**Definition Type**
Gaelic football					
Roe et al., 2018	Pro	Elite ♂ 1326 player seasons	-	Any injury that prevents a player from taking a full part in all training and match play activities typically planned for that day, where the injury has been there for a period greater than 24 h from midnight at the end of the day that the injury was sustained	TL
O'Connor et al., 2016	Pro	Collegiate ♂ n=217	19.3	Any injury sustained during training or competition resulting in time lost from play or player reported restricted performance	TL and RP
O'Connor et al., 2016	Pro	Adolescent ♂ n=292 Gaelic footballers and Hurlers	15.7	Any injury sustained during training or competition resulting in restricted performance or time lost from play	TL and RP
Murphy et al., 2012	Pro	Elite ♂ n=851	24.9	Any injury that prevents a player from taking a full part in all training and match play activities typically planned for that day, where the injury has been there for a period greater than 24 hours from midnight at the end of the day that the injury was sustained	TL
Wilson et al., 2007	Pro	Elite ♂ n=88	-	One that caused a player to miss one training or match or that required at least one treatment	TL and MA
Newell et al., 2006	Pro	Elite ♂ n=511	-	If he was unable to participate fully in training or games for a period of at least forty-eight hours after the injury was sustained	TL
Ladies Gaelic football					
O'Connor et al., 2020	Pro	Collegiate ♀ n=132		Any injury that prevents a player from taking a full part in all training and match play activities typically planned for that day, where the injury has been there for a period >24 hours from midnight at the end of the day that the injury was sustained	TL
Brown et al., 2013	Retro	Club ♀ n=74	26.8	Respondents were asked to only include injuries resulting from match play and practice	TL
Crowley et al., 2011	Retro	Club ♂ and ♀	-	Insurance claims from one county across one season of Ladies Gaelic football	MA
Hurling					

O'Connor et al., 2016	Pro	Adolescent ♂, n=292 Gaelic footballers and Hurlers	15.7	Any injury sustained during training or competition resulting in restricted performance or time lost from play	TL and RP
Blake et al., 2014	Pro	Elite ♂ n=856	24.3	A time-loss injury, that is, 'any injury that prevents a player from taking a full part in all training and match play activities typically planned for that day, where the injury has been there for a period greater than 24 h from midnight at the end of the day that the injury was sustained	TL
Murphy et al., 2010	Pro	Elite ♂ n=127		Any injury that prevents a player from taking a full part in all training and match play activities typically planned for that day, where the injury has been there for a period greater than 24 h from midnight at the end of the day that the injury was sustained	TL
Camogie					
O'Connor et al., 2019	Retro	All levels n=498	25.1	Any physical problem that may have caused pain, bleeding, loss of movement or loss of function in your body	RP
Buckley and Blake, 2018	Pro	Elite ♀ n=62	22.9	Any injury that prevents a player from taking a full part in all training and match play activities typically planned for that day, where the injury has been there for a period greater than 24 h from midnight at the end of the day that the injury was sustained	TL

TL: time loss; RP: restricted performance; MA: medical attention required; n: sample size; Pro: prospective; Retro: retrospective.

2.3.3 Reporting Injuries in Gaelic Games

Reporting injuries can be done in numerous ways, but the most common way to report injury in Gaelic games is incidence proportions or injury rates. Incidence proportion gives information on the proportion injured out of the total playing population at risk, generally over a specified time. However, the incidence proportion doesn't consider exposure. Injury rates, on the other hand, consider exposure hours. There are many ways to measure injury rates, such as per 1000 players' exposures, but each exposure may be of different lengths. Therefore it is recommended to be expressed as injuries per 1000 hours of exposure, which allows for comparisons across a range of sports.

2.3.3.1 Injury incidence proportion

Incidence proportion ranges from 32.5-69.0% in male Gaelic football (O'Connor et al., 2016; O'Connor et al., 2016; Murphy et al., 2012; Newell et al., 2006), 57.6-74.3% in Ladies Gaelic football (O'Connor et al., 2020; Brown et al., 2013), 32.5-82.0% in hurling (O'Connor et al., 2016; Blake et al., 2014; Murphy et al., 2010) and 23.0-88.2% in Camogie (Buckley and Blake, 2018; O'Connor et al., 2019).

2.3.3.2 Injury Rates

Although incidence proportions are helpful for reporting injuries, injury rates may be a superior reporting method as they consider exposure and the risk of sustaining an injury and may be more suitable outcomes for conditions with a sudden onset (Bahr et al., 2020). Injury rates can be calculated in several ways, but the most frequently used in Gaelic games is per 1,000 hours, allowing for comparison across age, gender, and sports. Injury rates vary across the different Gaelic games codes (Table 2.3). Gaelic football injury rates range from 9.2-13.5 injuries/1000 hours in males (Roe et al., 2018; O'Connor et al., 2016; Wilson et al., 2007; Newell et al., 2006; Blake et al., 2011). Ladies Gaelic football has higher injury rates than males (17.8 injuries/1000 hours) (O'Connor et al., 2020), indicating that injury prevention is a priority in women's sports. However, injury rates in Camogie were considerably lower (7.6 injuries/1000 hours) (Buckley and Blake, 2018) than in Ladies Gaelic footballers, possibly owing to the difference in demands between the sports. However, the Camogie study was a limited duration, and further longitudinal studies are warranted.

Injury rates are much higher in matches than in training in Gaelic games (Table 2.3), possibly due to the competitive nature and physicality involved in matches. Match injury rates have been as high as 12.9 times higher than training injury rates in male Gaelic football (Roe et al., 2018), 5.4 times higher in Ladies Gaelic football (O'Connor et al., 2020), as high as 19 times higher in hurling (Murphy et al., 2010) and 6.3 times higher in Camogie (Buckley and Blake, 2018). A systematic review and meta-analysis on male Gaelic football injuries found that the pooled match injury rate was 55.9 injuries per 1000 hours, and the training injury rate was 4.57 injuries per 1000 hours (Dekkers et al., 2022). Match injury rates in adult Ladies Gaelic footballers are also high (42.48 injuries /1000 hours), with a greater training injury rate (7.93 injuries / 1000 hours) compared with male Gaelic football (O'Connor et al., 2020). These match injury rates are higher than reported in other field-based codes such as AFL (36.94 injuries/1000 hours) and soccer (29.86 and 22.57 injuries/1000 hours, male and female, respectively) (Larruskain et al., 2018). Match injury rates in hurling ranged from 61.75-102.5 injuries per 1000 exposure hours (Blake et al., 2014; Blake et al., 2011; Murphy et al., 2010). Just one study looked at injury rates in elite-level Camogie, and match injury rates were 26.4 injuries per 1000 hours of exposure (Buckley and Blake, 2018). Although Camogie and hurling are very similar sports, the match injury rates were much less in the female sport of Camogie, which may be due to slight differences in the rules between the sports, such as more contact permitted in hurling such as shoulder-to-shoulder charges and Camogie matches lasting 60 minutes compared to 70 minutes in Hurling at the elite level (Camogie.ie, 2021). Hurling injury rates are higher than previously reported in other stick-based codes such as international male hockey (52.1/1000 hours) (Anderson et al., 2019). This may be due to Gaelic games being amateur and potentially having a lower level of injury prevention implementation.

It is clear that acute injuries in Gaelic games are prevalent, as demonstrated by the high incidence proportions and injury rates observed in Table 2.3. Injury risk reduction is critical to maximise sports safety and maintain high participation rates, which can lead to many physical and psychosocial benefits to players.

Table 2. 3. Incidence Proportion and Injury Rates in Previous Gaelic Games Research.

Author/ Year	Incidence Proportion	Total Injury Rate	Match Injury Rate	Training Injury Rate
Gaelic football				
Dekkers et al., 2022	-	-	55.90	4.57
Roe et al., 2018	-	9.2	49.8	3.9
O'Connor et al., 2016	47.4%	12.6	25.1	7.3
O'Connor et al., 2016	32.5%	4.9	9.3	3.0
Murphy et al., 2012	69%	-	61.9	4.1
Wilson et al., 2007	-	13.5	51.2	5.8
Newell et al., 2006	66%	11.8	64	5.5
Ladies Gaelic football				
O'Connor et al., 2020	57.6%	17.9	42.5	7.9
Brown et al., 2013	74.3%	-	-	-
Crowley et al., 2011	-	2.4	-	-
Hurling				
O'Connor et al., 2016	32.5%	4.4	2.3	11.1
Blake et al., 2014	71%	-	61.8	3.0
Murphy et al., 2010	82%	-	102.5	5.3
Camogie				
Buckley and Blake, 2018	23%	7.6	26.4	4.2
O'Connor et al., 2019	88.2%	-	-	-

Injury rate: injuries/1000 exposure hours; incidence proportion: (number of injured participants/number of participants at risk)*100; %: percentage.

2.3.3.3 Location of Injury

Across all four codes of Gaelic games, injuries predominately occur to the lower limb, accounting for 46.9-79.3% of all injuries (Table 2.4). Upper limb injuries (9.5-34.7%), head and neck injuries (3.1-18.4%) and trunk injuries (3.8-14.6%) occur less frequently in Gaelic games than lower limb injuries (Roe et al., 2018; O'Connor et al., 2016; O'Connor et al., 2020; Brown et al., 2013; Crowley et al., 2011; Blake et al., 2014; Murphy et al., 2010; Buckley and Blake, 2018). The most common injury locations are the posterior thigh, ankle and knee. In adult Gaelic games, 12.2% to as high as 31% of all injuries occur in the posterior thigh (Roe et al., 2018; O'Connor et al., 2016; Murphy et al., 2012; Wilson et al., 2007; Newell et al., 2006; O'Connor et al., 2020; Blake et al., 2014; Murphy et al., 2010; Buckley and Blake, 2018). The range may be due to differences in the different studies' injury definitions (Table 2.4). From the studies in adult Gaelic games, there seems to be a higher proportion of posterior thigh injuries in Gaelic football (12.2-31%) than in hurling/Camogie (14.3-16.5%) with 4 out of 6 studies reporting >15% in Gaelic games (Table 2.4). Hamstring injuries tend to occur during sprinting (Section 3.3.6), and elite Gaelic footballers (1596-1731m) cover a greater distance in matches while running at high speed (>17 km/h) than elite hurlers (759-1134m) (Section 2.1). This may be due to players having to carry the ball further and therefore have increased running demands in Gaelic football compared to hurling/Camogie, where the sliotar can travel beyond 65 meters at any one time (McIntyre, 2005) or due to different skills, e.g. soloing, toe pick-ups in males and increased kicking in Gaelic football.

From the prospective studies, ankle injuries range from 9-13.3% of all injuries in Gaelic games (Roe et al., 2018; O'Connor et al., 2016; O'Connor et al., 2016; Murphy et al., 2012; Wilson et al., 2007; Newell et al., 2006; O'Connor et al., 2020; Blake et al., 2014; Murphy et al., 2010; Buckley and Blake, 2018). Ankle injuries were similar for males and females and across all four codes of Gaelic games, indicating a similar scale of the problem. This needs to be addressed by adopting and implementing Gaelic games injury prevention exercise programmes. The risk of ankle injuries may be due to common game elements such as jumping and landing rather than the individual skills of the sports themselves.

From the prospective studies, knee injuries range from 2-19% of all injuries in Gaelic games (Roe et al., 2018; O'Connor et al., 2016; O'Connor et al., 2016; Murphy et al., 2012; Wilson et al., 2007; Newell et al., 2006; O'Connor et al., 2020; Blake et al., 2014; Murphy et al., 2010; Buckley and Blake, 2018). There was a lower proportion of knee injuries amongst adult male Gaelic footballers (11.1-14.1%), hurlers (7.4-11.9%) and Ladies Gaelic footballers (12.6%) than Camogie players (19%). Although just a subset of knee injuries, a female player is twice as likely to sustain an ACL injury, and a female player is a vulnerable group for this injury (Beynnon et al., 2014). This may be due to several factors, such as access to and experiences with training and access to the coaching staff and medical personnel (Parsons et al., 2021). Similarly, it may be due to differences in neuromuscular control, and anatomical and hormonal differences. Females are less effective at stiffening their knees and have increased anterior tibial laxity and decreased strength and endurance than males (Wojtys et al., 2002; Huston and Wojtys, 1996). Regarding anatomy, males have a larger femur and smaller Q angle than females (Ireland, 2002). (Therefore injury prevention for female Gaelic games should focus on targeting knee injuries.

Head and neck injuries also appear more frequently in female Gaelic games (9.5-18.4%) than in male Gaelic games (3.1-5.4%) (Roe et al., 2018; O'Connor et al., 2016; O'Connor et al., 2020; Blake et al., 2014; Murphy et al., 2010; Buckley and Blake, 2018). A concussion is a common head/neck type injury. Females are at a greater risk of concussion than males and are at 84% higher risk of concussion following a head or neck injury (Koerte et al., 2020; Chandran et al., 2020). The higher risk of head injuries or concussions in females may be due to having decreased head and neck strength and decreased neck girth compared to males (Bretzin et al., 2017), as well as females, are more likely to disclose symptoms of concussion (Wallace et al., 2017).

Thus, the research indicates that most injuries occur in the lower limb in Gaelic games. Hamstring injuries, in particular, frequently occur in Gaelic games, followed by ankle and knee. Hamstring injuries were the number one location of injury in all prospective adult studies except for two. Therefore injury prevention exercise programmes should focus on reducing injuries in the hamstring in particular. To do this, understanding the aetiology of this common injury site is required to develop tailored injury prevention exercise programmes for the different groups of Gaelic game players. Although these injuries frequently occur in Gaelic games, they may not have the most significant adverse effect on teams, and therefore the burden of injury must also be considered.

Table 2. 4. Location of Injury in Previous Gaelic Games Research.

	Gaelic Games Code												
	Male Gaelic Football						*Ladies Gaelic Football*			*Hurling*			*Camogie*
	Author & Year												
Location (%)	Roe et al., 2018	O'Connor et al., 2016	O'Connor et al., 2016	Murphy et al., 2012	Wilson et al., 2007	Newell et al., 2006	O'Connor et al., 2020	Brown et al., 2013	Crowley et al., 2011	O'Connor et al., 2016	Blake et al., 2014	Murphy et al., 2010	Buckley and Blake, 2018
Lower Limb	79.9	71.1	-	76.0	71.1	70.0	67.1	46.9	58.0	-	70.1	68.3	71.4
Ankle	11.7	11.3	12.0	10.0	13.3	9.0	10.3	19.4	20.0	10.0	9.3	9.0	9.4
Foot/ toes	-	2.8	2.7	2.8	-	-	1.3		-	2.0	3.5	9.0	4.8
Shin	-	1.4	0	1.0	-	-	3.8	-	-	2.0	2.9		-
Calf	4.3	5.6	6.7	5.2	-	-	1.3	-	-	6.0	5.0	6.0	14.3
Knee	11.1	14.1	18.7	11.3	-	15.0	12.7	10.2	33.0	2.0	11.9	7.4	19.0
Posterior thigh	23.9	15.5	13.3	24	12.2	31.0	21.55	8.2	10.0	4.0	22.9	16.5	14.3
Anterior thigh	9.3	6.3	8.0	9.3	12.2	-	11.34	-	-	4.0		9.0	9.4
Hip	-	7.7	5.3	3.1	-	-	2.5	7.1	-	0.0	2.3	4.5	-
Groin	14.9	6.3	8.0	9.4	-	14.0	2.5	-	-	10.0	10.3	9.0	-
Trunk	6.6	9.2	-	-	-	-	3.8	-	-	-	8.6	9.3	14.6
Back	1.3	3.5	5.3	0		-	1.3	-	-	22.0		9.3	4.8
Rib/ chest	-	3.5	0	0	4.4	-	0	-	-	4.0	-	4.7	4.7
Upper limb	10.5	16.2	-	-	-	-	13.9	34.7	24.0	-	18.4	15.1	9.5
Shoulder	4.1	4.2	6.7	6.2	-	15.0	1.3	-	20.0	6.0	7.1	2.9	-
Elbow	-	0.7	0	1.2	-	-	2.5	-	-	2.0	0.1		-
Forearm	-	0.7	0	0	-	-	2.5	-	-	0.0	1.1	12.2	-
Wrist	-	1.4	1.3	1.0	-	-	2.5	-	-	6.0	1.5		-
Hand/ fingers	-	9.2	10.7	1.5	-	-	3.8	22.5	15.0	0.0	8.8		9.5
Head/ neck	2.8	3.5	-	3.6	-	-	12.7	18.4	18.0	-	4.1	5.4	9.5
Head	-	2.8	0	-	7.7	-	10.1	-	-	0.0	-	-	9.5
Neck	-	2.8	1.3	-	-	-	0.0	-	-	2.0	-	-	-

2.3.3.5 Injury Severity and Burden

Injuries in Gaelic games can lead to substantial reductions in player availability, with 29.8-41.6% of injuries resulting in greater than three weeks absent from sport (Table 2.5) (O'Connor et al., 2016; Murphy et al., 2012; Newell et al., 2006; O'Connor et al., 2020; O'Connor et al., 2016). Mean time loss ranges from 12-25.7 days absent (Buckley and Blake, 2018; Blake et al., 2014; O'Connor et al., 2020; Roe et al., 2018). Hurling and Camogie injuries (12 days absent) have almost half the mean time loss than Gaelic football injuries (23.54-25.7 days absent). The particular injury burden needs to be examined in order to explain the differences and develop targeted interventions.

It has been argued that epidemiology needs to move on from reporting injury rates and severity in isolation (Bahr et al., 2017) because the burden of injury provides us with the consequence of injuries rather than the number of injuries (Bahr et al., 2020). The burden is a cross-product of incidence and severity ('injury incidence × mean absence per injury'), thus accounting for both the frequency and severity of injuries and expressed as days absent per 1000 player hours. This gives clinicians a better understanding of the injury's consequences for the team/management (Hägglund et al., 2013). Therefore, the focus of developing injury prevention programmes must be based not only on frequent injuries but also on those that substantially impact player availability (Bahr et al., 2017). However, just three studies in Gaelic games examine injury burden, all of which examined Gaelic football (Table 2.6). Knee injuries have a significant burden of injury, with a higher burden noted in female collegiate Gaelic footballers (106.5 days absent per 1000 hours) compared to male collegiate Gaelic footballers (80.8 days absent per 1000 hours) (O'Connor et al., 2020; O'Connor et al., 2016). Knee ligament injuries in elite level soccer in Australia have a lower injury burden of 53 days absent per 1000 hours, possibly due to the elite level having better access to medical professionals and resources for injury prevention and rehabilitation (Whalan et al., 2019). The high burden of knee injuries in Gaelic games may be due to the long rehabilitation process after ACL injuries, a subset of knee injuries. As female players are twice as likely to sustain an ACL injury (Beynnon et al.,2014), as previously described in section 2.3.3.3.

Table 2. 5. Injury Severity in Previous Gaelic Games Research.

Author & Year	**Definition**	**Minor (%)**	**Moderate (%)**	**Severe (%)**	**Mean Time loss (Days)**
Gaelic Football					
Roe et al., 2018	Mild (1–7 days), moderate (8–28 days), severe (29+ days)	27.0	49.8	23.2	25.7
O'Connor et al., 2016	Minor (≤7 days), moderate (8–21 days), and severe (>21 days)	34.8	29.8	35.5	-
O’Connor et al., 2016	Minor (≤7 days), moderate (8–21 days), and severe (>21 days)	41.7	20.8	37.5	-
Murphy et al., 2012	Mild (1–7 days), moderate (8–28 days), severe (29+ days)	13.2	45.2	41.6	-
Newell et al., 2006	Minor (≤7 days), moderate (8–21 days), and severe (>21 days)	10.0	56.0	34.0	-
Ladies Gaelic Football					
O'Connor et al., 2020	Minor (≤7 days), moderate (8–21 days), and severe (>21 days)	25.6	37.2	37.12	23.5
Hurling					
O’Connor et al., 2016	Minor (≤7 days), moderate (8–21 days), and severe (>21 days)	61.7	8.5	29.8	-
Blake et al., 2014	-	-	-	-	12.0
Murphy et al., 2010	Minor (≤7 days), moderate (8–28 days), and severe (>28 days)	45	45.5	9.5	-
Camogie					
Buckley and Blake, 2018	-	-	-	-	12.4

Hamstring injuries do not just have a high prevalence, they also have a significant burden of injury in both males and females. In one study of elite males, hamstring injuries had the greatest burden of all injuries (Roe et al., 2018). In the two studies on collegiate players, hamstring injuries had the second greatest burden of injury (O'Connor et al., 2020; O'Connor et al., 2016). The burden of hamstring injuries was higher in female collegiate Gaelic footballers (66.12 days absent per 1000 hours) than in male elite (52.9 days absent per 1000 hours) and male collegiate Gaelic footballers (38.6 days absent per 1000 hours) (O'Connor et al., 2020; O'Connor et al., 2016; Roe et al., 2018). Again, this is higher than reported in elite level soccer (36 days absent per 1000 hours) (Whalan et al., 2019). As Gaelic games are amateur sports, players may be less conditioned and, therefore, may be at a greater risk of musculoskeletal injury in Gaelic games. Men were 64% more likely than women to sustain a hamstring strain in collegiate soccer (Cross et al., 2013); however, females had a more significant burden in Gaelic games. The increased burden in Ladies Gaelic footballers could be as females are two times more likely to take longer than six weeks to return to play after a muscle injury (Shariff et al., 2013). One study found that Ladies Gaelic footballers had significantly less confidence in their ability to return to pre-injured levels compared to male collegiate Gaelic footballer and although not significant female players also reported lower overall confidence to play after injury (O'Connor et al., 2021). Similarly, previously injured females perceived a significantly higher probability of risk of future injury and reported increased worry/concern about their injuries compared to males (Short et al., 2004). Therefore females may be more likely to make sure they are fully rehabilitated before returning to the sport than males to minimise the risk of future injury. Short et al. (2004) have claimed that similar reasoning may be applied to sports, with players who perceive a greater risk of injury being more concerned about the repercussions of injury (e.g., pain, loss of playing time, incapacity).

Similarly, ankle injuries also have a significant burden in both male and female Gaelic Footballers (20.1-52.8 days absent per 1000 hours) (O'Connor et al., 2020; O'Connor et al., 2016; Roe et al., 2018). Ankle injury burden was at least double in collegiate Gaelic football (39.9-52.8 days absent per 1000 hours) than in elite level Gaelic football (20.1 days absent per 1000 hours). Non-elite players may not have the same resources as elite players, such as the availability of qualified medical personnel during practice and competition, which influences their management and ability to return to play in a timely way (Putukian et al., 2009). Therefore emphasis should be placed on minimising injuries by implementing injury prevention exercise programmes in the non-elite populations.

Groin injuries had a large burden in elite male Gaelic footballers (28.6 days absent per 1000 hours) compared to the collegiate level and are more of an issue in males than females (Table 2.6) (O'Connor et al., 2016; Roe et al., 2018). Groin injuries are much more common in males than females in other sports also (RR=2.5) (Orchard, 2015). Possible explanations for this increased risk in males could be due to sex and anatomical characteristics of the groin and pelvis (Schache et al., 2017), and training and match loads or intensities (Waldén et al., 2015). Similarly, groin injuries are common in other football codes, including twisting, turning, sprinting and changing direction (Orchard et al., 2015). The increased burden in elite level players may be due to an increased training load in elite players in Gaelic games, groin injuries developing from long-standing groin issues, and players potentially being older on elite teams as increased age is a risk factor for injury in both soccer and rugby (Arnason et al. 2004; O'Connor, 2004).

Not only do injuries have a burden in terms of days absent, they can also have a financial burden on both the players and the club. Male Gaelic games players have a rate of 2.92 claims per club per year (Roe et al., 2016). This is greater than Ladies Gaelic football, with 1.15 claims per club per year (O'Connor et al., 2022). The value of the claims is higher in male Gaelic games (€1158.40) compared with Ladies Gaelic football (€663.30) (Roe et al., 2016; O'Connor et al., 2022). However, in both male and female Gaelic games, the value of claims is increasing yearly (Figure 2.2). Lower limb injuries account for two in every three claims in both male Gaelic games and Ladies Gaelic football and account for greater than four-fifths of the total cost of claims (Roe et al., 2016; O'Connor et al., 2022). The knee, ankle and hamstring are the most prevalent injury site (Roe et al., 2016; O'Connor et al., 2022), similar to injury rates and burden discussed earlier in this section. In Ladies Gaelic football, 87% of hospitalizations were from knee injuries. Therefore effective injury prevention exercise programmes must be developed considering these high medical costs and gender differences.

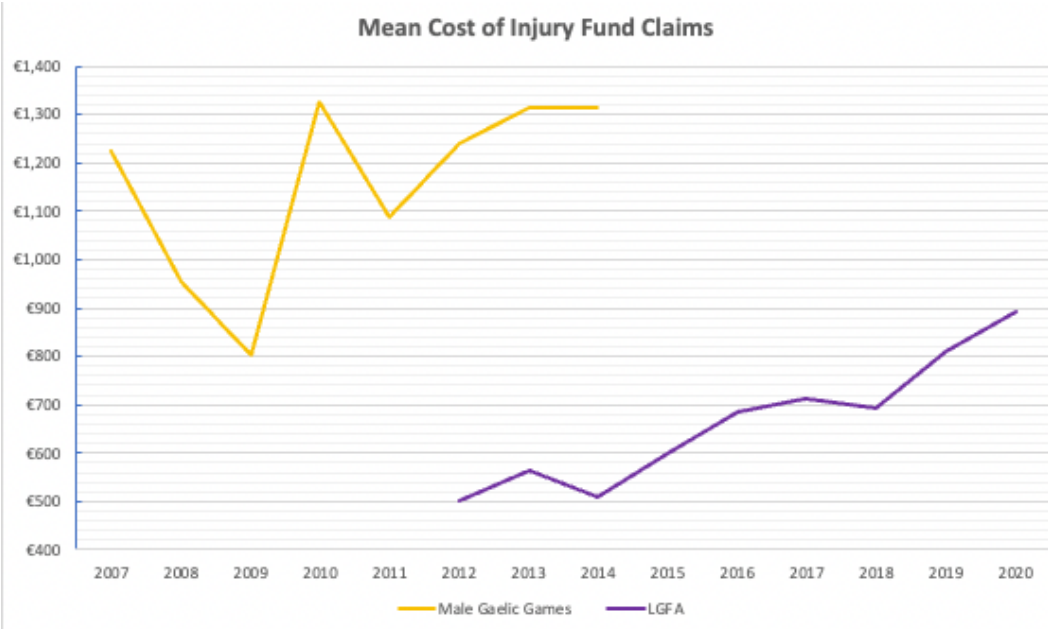

Figure 2. 2. Mean injury claim trends in male Gaelic games and Ladies Gaelic football.

There is some overlap between the frequent injuries and the injuries with the most significant burden regarding time loss and finances. From the location and the burden of injury (TRIPP stage 1), we can conclude that injury prevention programmes for Gaelic games should focus on the lower limb, especially the hamstrings. Targeted injury prevention exercise programmes could minimise the risk of injuries and related expenses and enhance player availability, leading to improved performance. Further research is required looking at the burden of injury in Gaelic games as a whole, as there is a paucity of research in hurling/Camogie and elite Ladies Gaelic football. It is recommended that looking at injury burden is important for epidemiological studies, which is the first stage and an essential aspect of developing injury prevention exercise programmes (Bahr et al., 2017). To develop injury prevention strategies, a detailed understanding of the aetiology and mechanisms of these injuries is required (TRIPP stage 2).

Table 2. 6. Injury Burden in Previous Gaelic Games Research.

	Gaelic games code		
	Gaelic Football		Ladies Gaelic football
	Author/ Year		
	Roe et al., 2018	O'Connor et al., 2016	O'Connor et al., 2020
Location			
Ankle	20.1	52.8	39.9
Foot/ toes	-	14.3	2.2
Shin	-	13.3	12.8
Calf	11.7	5.1	1.1
Knee	22.4	80.8	106.5
Posterior thigh	52.9	38.6	66.1
Anterior thigh	16.3	20.5	31.3
Hip	-	27.9	9.3
Groin	28.6	25	7.1
Back	8.4	31.1	4.4
Neck	-	-	-
Ribs/Chest	-	9.1	-
Shoulder	10	39.3	1.3
Head	-	6.1	27.6
Elbow	-	-	9.3
Wrist	-	4.8	4.4
Hand/fingers	-	26.8	7.9
Forearm	-	-	18.7

Injury burden: days absent per 1000 player hours.

2.3.3.6 Mechanism of Injury

Alongside injury location, understanding the aetiology, or how injuries occur, is crucial for injury prevention practices (van Mechelen et al., 1992). This is the second step in the TRIPP model, and without knowing the mechanisms, the preventative programmes' specific aims and targets are unknown (Finch, 2006). A transfer of energy to the tissue and the relation between load applied and load tolerance of that tissue determines if an injury occurs (Bahr and Krosshaug, 2005). The incident either resulted in a mechanical load that was greater than what could have been accepted under normal conditions or it decreased the tolerance levels to the point where a normal mechanical load could not have been sustained (McIntosh, 2005). The stiffness, strength, and critical stress of human tissue, among other mechanical characteristics, determine how the body reacts to physical pressures (McIntosh 2005). They vary for each tissue and rely upon the type of load, its velocity, the magnitude of energy transfer, and other intrinsic characteristics. Injuries occur if the stress on a tissue exceeds the tissue's capacity to withstand the stress (Kalkhoven et al., 2020). Although the leading causes of a sporting injury, stresses and strains can, when managed correctly, provide vital stimuli for optimal physiological and mechanical adaptation (Kalkhoven et al., 2020).

The forces a player is subjected to and the load capabilities of the various bodily structures are primarily determined by physiology. It has been suggested that the relationship between load and load capacity plays a significant role in injury development, and the mechanism for an injury occurs when the cumulative load placed on a particular structure exceeds that structure's capacity (Hreljac, 2005; Soligard et al., 2016). The nature of the loading pattern experienced determines the type of injury (Figure 2.3). The key distinction is that the event either produced a mechanical load that was more than what would typically be tolerated or decreased the tolerance levels to the point where a typical mechanical load would no longer be tolerated (McIntosh, 2005). The two types of stress can be applying a single, high-magnitude stress or, alternately, applying a load repeatedly (Kalkhoven et al., 2020). A tissue's strength is its capacity to endure an applied load. Structural failure occurs when the amount of stress and strain sustained is greater than the strength of a given tissue leading to rupture or macrotrauma in an acute injury (Kalkhoven et al., 2020). The mechanical loading pattern that leads to a chronic injury includes microdamage and tissue fatigue caused by the repetitive stress placed on the tissues (Edwards, 2018). The muscle tissue stress may be due to passive or active stretch in the presence of an eccentric contraction (Garrett, 1996). Two experimental studies on animals found that the primary source of injury was due to excessive strain regardless of muscle activation and force generated by the muscle (Garrett, 1990; Lieber and Friden, 1993).

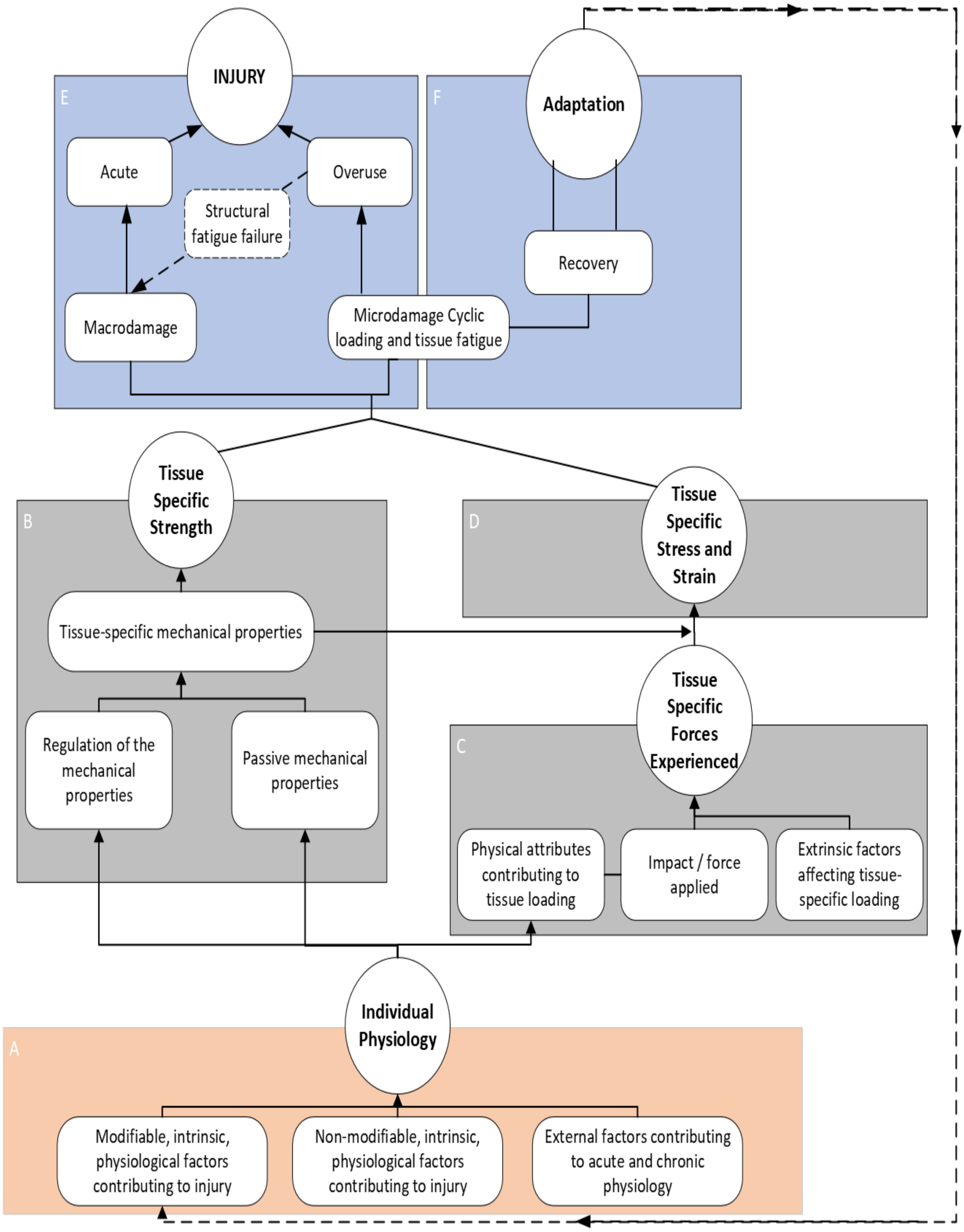

Figure 2. 3. A detailed framework for stress-related, strain-related, and overuse injury (Kalkhoven et al., 2020).

Injuries are generally non-contact in Gaelic games and occur 2.8 times more frequently than contact injuries (Roe et al., 2018). A non-contact mechanism of injury was involved in almost half to over two-thirds of all injuries (Table 2.7). Only in Camogie are contact injuries (52.4%) more frequent than non-contact injuries (Buckley and Blake, 2018). However, this study only included three teams and concluded when all teams were eliminated from the championship, so further comprehensive research is needed. As injuries are predominantly non-contact, successful injury prevention exercise programmes may reduce these non-contact injuries.

From Table 2.7 it is evident that sprinting injuries are common across all four codes accounting for almost a fifth of injuries in Gaelic games (Gaelic football (14.4-26.8%); Ladies Gaelic football (38.0%); hurling (20.8-24.5%); Camogie (19%)) (O'Connor et al., 2016; O'Connor et al., 2016; O'Connor et al., 2020; Blake et al., 2014; Buckley and Blake, 2018). This may suggest why there is such a high prevalence of hamstring injuries (Table 2.4) in Gaelic games, as 73.4% of hamstring injuries that occurred in Gaelic football occurred while sprinting (Roe et al., 2016). This is similar to other field-based sports such as AFL (80%), soccer 60%) and rugby (68%) (Gabbe et al., 2005; Woods et al., 2004; Brooks et al., 2006). It has been suggested that excessive muscle strain in eccentric contraction while the muscle is lengthening as the primary mechanism of hamstring muscle strain injury while sprinting (Yu et al., 2017). Hamstring injuries occur during sprinting, specifically the terminal swing phase when the muscle is lengthened and working eccentrically, where the hip is flexed, and the knee is extending (see section 2.4.3 for greater detail). The hamstring muscles are active at this stage while lengthening, which could induce an eccentric contraction injury as they are working to decelerate hip flexion and knee extension (Thelen et al., 2005; Schache et al., 2009). Therefore, when hamstring strain injury occurs while sprinting, the hamstrings are stretched beyond their capacity while producing an eccentric contraction. There is a large amount of sprinting and high-speed running in Gaelic games (section 2) which may increase the risk of hamstring injuries. Therefore high-speed running volumes and eccentric hamstring strength must be examined as risk factors for injury in Gaelic games players which may result in injury prevention strategies that may reduce the risk of these injuries.

Table 2. 7. Mechanism of Injury in Previous Gaelic Games Research

	Gaelic Games Code							
	Gaelic Football				Ladies Gaelic Football	Hurling		Camogie
	Author/ Year							
Mechanism (%)	O'Connor et al., 2016	O'Connor et al., 2016	Murphy et al., 2012	Wilson et al., 2007	O'Connor et al., 2020	O'Connor et al., 2016	Blake et al., 2014	Buckley and Blake, 2018
Non-contact	52.1	64.0	67.8	-	66.3	63.3	61.4	47.7
Contact	47.9	36.0	32.2	-	33.8	36.7	38.6	52.3
Running/Sprinting	24.8	25.7	26.8	14.4	38.0	20.8	24.5	19.0
No Specific	9.9	24.3	-	-	10.1	27.1	15.0	9.4
Landing	9.2	4.1	7.1	-	7.6	4.2	13.7	-
Tackling	7.1	2.7	32.2	10.0	7.6	8.3	38.6	19.0
Being Tackled	13.5	12.2		17.9	7.6	16.7		
Falling	2.8	2.7	-	-	7.6	10.4	-	-
Kicking	7.8	9.5	4.5	-	6.3	-	0.3	-
Turning	8.5	5.4	12.0	13.3	6.3	4.2	7.1	14.3
Jumping/Catching	8.5	10.8	-	-	5.1	6.3	-	-
Blocking	5.7	1.4	-	-	3.8	2.1	-	-
Sudden Stop	2.1	-	-	-	-	-	-	-
Warm up	-	-	-	-	-	-	0.9	-
Push Off	-	-	-	-	-	-	-	4.8
Contact with ground/equipment	-	1.3	-	-	-	-	-	33.3

Landing is a common mechanism of injury in Gaelic games (4.1-13.7%) (Table 2.7) (O'Connor et al., 2016; O'Connor et al., 2016; O'Connor et al., 2020; Blake et al., 2014; Buckley and Blake, 2018). Landing may contribute to injuries such as knee and ankle sprains which have a large proportion and burden of injury in Gaelic games. Landing is one of the top three mechanisms for an ACL sprain injury (Walden et al., 2015) and similarly was observed in 87.5% of ankle injuries in volleyball (Skazalski et al., 2018). It is proposed that ACL injuries can occur during landing if an athlete has limited hip and knee flexion so that the musculature may not have the ability to dissipate the force, causing an overload on the passive structures (Hashemi et al., 2007; Waldén et al., 2015). Similarly, poor landing technique has been proposed to contribute to acute and chronic knee injuries (van der Does et al., 2015). Van der Does et al. (2015) also found that increased dorsiflexion moment of the ankle and instability when landing from forward and diagonal jumps increased the risk of ankle sprain injuries. As landing contributes to many injuries, appropriate landing techniques and neuromuscular control should be included in prevention programmes.

Kicking is a fundamental component of Gaelic football. Kicking is the mode of passing 30% of the time (Mangan et al., 2017), with matches typically having 205 kicks per match (Ball and Horgan, 2013). Kicking in Gaelic football accounts for 4.5-9.5% of all injuries (O'Connor et al., 2016; O'Connor et al., 2016; O'Connor et al., 2020). Kicking is the mechanism for 4.4% of all hamstring injuries in Gaelic football (Roe et al., 2016), much less than in Australian rules football(17.9%) (Opar et al., 2015). However, this could be due to kicking becoming less frequent in Gaelic football in the modern-day (Lynch and Carroll, 2017). Kicking is a momentum-assisted motion, a multiarticular movement characterised by a proximal-to-distal motion of the lower limb segments of the kicking leg (Navandar et al., 2018). Kicking typically includes a diagonal movement from hip extension to flexion, and hip abduction to adduction with the hip externally rotated (Serner et al., 2019). Therefore, many different muscles are required, such as hamstrings, quadriceps and adductors, that contribute to kicking and may be at risk of injury during kicking. The kicking leg is moved posteriorly by concentric muscle contraction of the hip extensor muscles, which start the backswing. More hip extension and thigh range of motion are made possible by a longer final step, enhancing foot speed and distance (Ball, 2008). During the wind-up phase (the initial part of the forward leg cocking phase, transitioning from the backswing phase), the rectus femoris is working eccentrically to decelerate hip extension and wind up or start hip flexion (Figure 2.4) (Mendiguchia et al., 2013). The contralateral limb that is in contact with the ground can also be at risk of injury as the body leans backwards to decelerate, which puts stress and strain on the rectus femoris (Mendiguchia et al., 2013). During the cocking phase, as the knee rapidly extends and makes contact with the ball, the hip continues to flex. After making first contact with the ball, the follow-through continues until full knee extension. Maximum knee extension and hip flexion is the final position known as the end of follow-through. The hamstring muscle complex is most vulnerable to injury during the follow-through phase when the hip is flexed, and the knee begins to flex from a fully extended posture (Navandar et al., 2018). For the adductors, maximal adductor longus activation occurs in the backswing phase, while the maximal length of the adductor longus is seen in the cocking phase (the position of maximum hip extension, transitioning to the hip flexion acceleration) (Serner et al., 2018). Serner et al. (2018) suggest that the rapid change from hip extension to hip flexion while kicking puts the adductor longus at risk of injury while the muscle is undergoing rapid lengthening. This occurs when the thigh decelerates and changes direction in open-chain injury activities and when upper body propulsion is controlled in closed-chain injury actions (Serner et al., 2018).

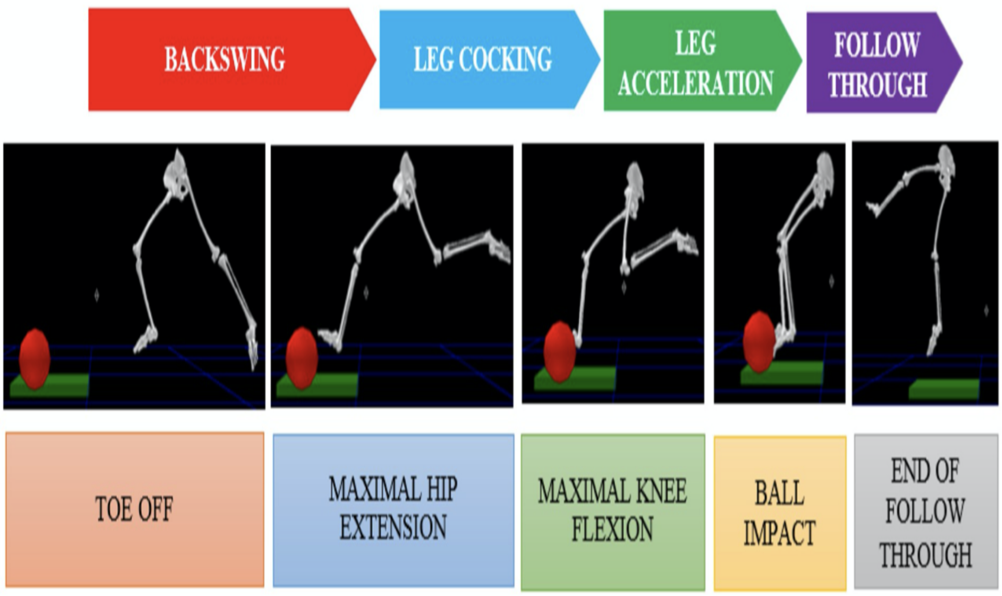

Figure 2. 4. The breakdown of the kick (Navandar et al., 2018).

2.3.4 Comparison with Comparable Sports

Gaelic games are unique due to several different sports, their unique playing demands and amateur status. However, it is essential to understand how Gaelic games compare with some comparable sports in terms of injury rates and the location of injuries. A recent meta-analysis that included seven sports found that males had an increased injury rate compared to females but was only significant in soccer and handball (Zech et al., 2022). Injury rates for underage Gaelic footballers were less than male (5.7 injuries/1000 hours) and female (6.8 injuries/1000 hours) soccer players (Robles-Palazón et al., 2022) and AFL players (8.1 injuries/1000 hours) (McMahon et al., 1993). The most common location of injury for male soccer players and AFL players were the thigh, ankle and knee and similarly for female soccer players were the ankle, knee and thigh (Robles-Palazón et al., 2022; McMahon et al., 1993). In youth and senior soccer, the most common types of injury are strains, sprains and contusions (Pfirrmann et al., 2016). The location of injury was similar for both youth and senior soccer, with the thigh having the greatest injury rate (1.8 injuries/1000 hours), followed by the knee (1.2 injuries/1000 hours) and ankle (1.1 injuries/10000 hours) (López-Valenciano et al. 2020). In elite adult soccer, injury rates were higher for male players during both training (4.7 vs 3.8 injuries/1000 hours) and match play (28.1 vs 16.1 injuries/1000 hours) (Hägglund et al., 2009) female players suffered injuries at a rate 24% lower than male players (6.8 vs 5.2 injuries per 100 players). Yet, female soccer players sustained significantly greater number of severe injuries (Mufty et al., 2015). Possible explanations for the increased severity of injuries in female players could be that the female leagues have a lower level of professionalism; hence the majority of the players could also be doing other jobs in addition to soccer (Mufty et al. 2015; Hägglund et al., 2009). Female soccer players experience a lot of stress on their bodies due to the male-like schedule of today's elite female soccer, which makes it difficult for them to prepare appropriately in training, adequately, or have proper nutrition. Similarly, female soccer players have less medical support than their male counterparts, which could result in delayed injury diagnosis and less effective rehabilitation (Mufty et al., 2015; Hägglund et al., 2009). To date, there are no prospective epidemiological studies in female AFL. However, a questionnaire found that 78% of female athletes had sustained an injury over one season (Fortington et al., 2016). The lower limb was involved in more than half (55%) of all worst injuries, with joint injury accounting for half of these injuries (29% of all injuries). Ankle ligament sprains (12%), knee ligament sprains (10%), and thigh strains (6%) were the locations with the most significant number of injuries (Fortington et al., 2016). Almost 1 in 5 (17%) injuries caused the player to miss six games or more due to injury (Fortington et al., 2016).

As previously described, hurling/Camogie are stick-based field sports. Lacrosse could be considered a similar stick-based sport primarily played in the United States with rapidly growing participation numbers (Barber Foss et al., 2018). In youth lacrosse players, boys had a higher injury rate (2.9 injuries/1000 athlete exposures) compared to girls (2.5 injuries/1000 athlete exposures) (Hinton et al., 2005). The three most common locations of injuries were similar for both boys and girls: the ankle, knee and head/face. However, boys had a three times greater risk of neck injuries and a two times greater risk of shoulder and upper thigh injuries. This may be because females are not permitted to make body contact in lacrosse (Vincent et al., 2015). A recent review found that of the prospective studies on female lacrosse, the injury rates ranged from 0.7-3.9 injuries/1000 athlete exposures (Barber Foss et al., 2018). Although a direct comparison cannot be made due to the expression of injury rates, this suggests it is less than elite Camogie (Table 2.3). The ankle (17.7%), knee (10.9%) and thigh (10.9%) are the most common locations of injury (Matz and Nibbelink, 2004). However, head injuries have previously been described as the number one injury (30.1%) in a retrospective study (Waicus and Smith, 2002), and female players have an increased risk of head/face injuries compared to males (Lincoln et al., 2007; Barber Foss et al., 2018). However, there is no significant difference in total injury rates across genders for adult lacrosse players, with the most common location of injury being the lower limb (Hasan et al., 2023). Therefore, injury rates in male hurling are higher (Table 2.3) than in a similar stick-based game such as lacrosse.

As previously mentioned, Gaelic games are incredibly unique sports. Although considered amateur, Gaelic games can have injury rates as high or higher than professional sports with some similar demands. It is critical that further epidemiological research is carried out across all codes of Gaelic games and at various levels, as the location of injury and injury rates only sometimes translate across similar sports, levels and genders, as highlighted by section 2.3.4.

2.3.5 Summary

As was highlighted in this section, injuries are common in Gaelic games and lead to a substantial time loss and burden. The most common injuries and those with the highest burden are lower limb injuries, particularly the hamstring, knee and ankle injuries. Injuries in Gaelic games most commonly occur during activities such as sprinting, landing and kicking. Due to the frequency of injury and negative impact on player availability, injury prevention strategies that include injury prevention exercise programmes should be implemented and adhered to, which could make Gaelic games safer and reduce the high dropout rates associated with injury in Gaelic games (Lunn et al., 2013). In order to develop successful injury prevention exercise programmes, more epidemiological studies are needed, especially those that look at injury burden in hurling and Camogie. Understanding the risk factors for specific, common injuries in Gaelic games is required in order to develop and evaluate injury prevention exercise programmes (TRIPP stage 2).

2.4 Aetiology of Hamstring Injury

2.4.1. Aetiology of injury

The first step of the TRIPP framework is to identify the magnitude of the problem in Gaelic games described in the previous section. The next step is establishing the aetiology and mechanisms of injury (Finch, 2006). Knowing the causes of any specific type of injury in a given sport requires knowledge of the functional anatomy, aetiology, and mechanisms of injuries, allowing for the development of preventative measures (Bahr and Krosshaug, 2005). Aetiology relates to the cause of or why an injury occurs (Meeuwisse, 1994). To advance the understanding of injury epidemiology, Meeuwisse et al. (2007) developed a model that accounts for the multifactorial approach to the aetiology of injury (Figure 2.5).

2.4.1.1 Development of an Aetiology of Injury Model

Injury risk management is critical for maximising player performance and availability (Roe et al., 2017; Meeuwisse et al., 2007; Meeuwisse, 1994). Although the incident leading to an injury may appear as a single inciting event, it may result from a complex interaction between a number of different internal and external risk factors. Although one intrinsic or extrinsic risk factor alone may cause injury, it has been suggested that one is not usually sufficient for injury to occur, rather the sum of the two factors or the interaction between them as the injury is multifactorial (Meeuwisse, 1994; Meeuwisse et al., 2007). The final link in the chain for injury to occur is the mechanism of injury or inciting event (Meeuwisse, 1994). An "inciting event" is necessary to initiate an injury, which is mainly associated directly with the onset of injury in the case of acute injuries but could be less apparent in the instance of injuries with gradual onset. However, much of the focus is often placed on the inciting event and little attention on the risk factors that precede the inciting event (Meeuwisse et al., 2007). To understand the aetiology, an understanding of risk factors and the mechanism of injury is required.

Initially, the multifactorial model of injury aetiology (Meeuwisse, 1994) was developed but had limitations when explaining how risk variables change over time in response to the cyclical pattern of exposure, injury, and return to sport. The model was too linear and over-simplistic and does not emphasise that frequent engagement might lead to changes in injury vulnerability because of adaptations or maladaptations. Hence Meeuwisse et al. (2007) extended the model to “a dynamic, recursive model of aetiology in sports injury" (Figure 2.5). A player's intrinsic risk characteristics and susceptibility to an injury in a real-life sports setting are not rigid but dynamic and can regularly alter by just one exposure to a possible inciting incident (Figure 2.5). The player may be less susceptible to injury if the intrinsic risk factor improves, but if there is a maladaptation, the risk of injury may rise (Meeuwisse et al., 2007). Similarly, the same reasoning may be used to explain changes in extrinsic risk factors, where the player's behaviour may alter due to the nature of the activities.

The susceptible player may or may not get injured, and if no injury occurs, the modification of risk factors occurs. This model made significant strides in understanding the aetiology of sports injuries because it proposes that participating in sports may lead to repeated alterations in injury susceptibility and that exposure to key risk factors might result in adaptations and constantly alter risk. A recursive loop (feedback) is a critical feature of a complex system in which the output is reprocessed and generates fresh input for the system (Bittencourt et al., 2016). This looping 'global to local' cycle illustrates that the global pattern develops through interactions among local units and that the global pattern impacts and constrains the interactions of the local units. This inciting event may cause the body to adapt positively and benefit from reducing injury risk. However, there is the potential for the opposite to be true in the case of maladaptation, and the player may be more predisposed to injury (Meeuwisse et al., 2007). As this dynamic and recursive model assumes that there may be recurrent changes in susceptibility to injury during sports participation and that primary risk factors exposure can produce adaptations and continuously change the risk, this model has made significant contributions to our understanding of sports injury aetiology (Bittencourt et al., 2016). The dynamic model has achieved this by identifying that risk factors should not be looked at in isolation, risk factors fluctuate when exposed to the inciting event and can adapt positively or negatively, altering the risk factor. Therefore regular season screening of risk factors and their interaction with one another is recommended.

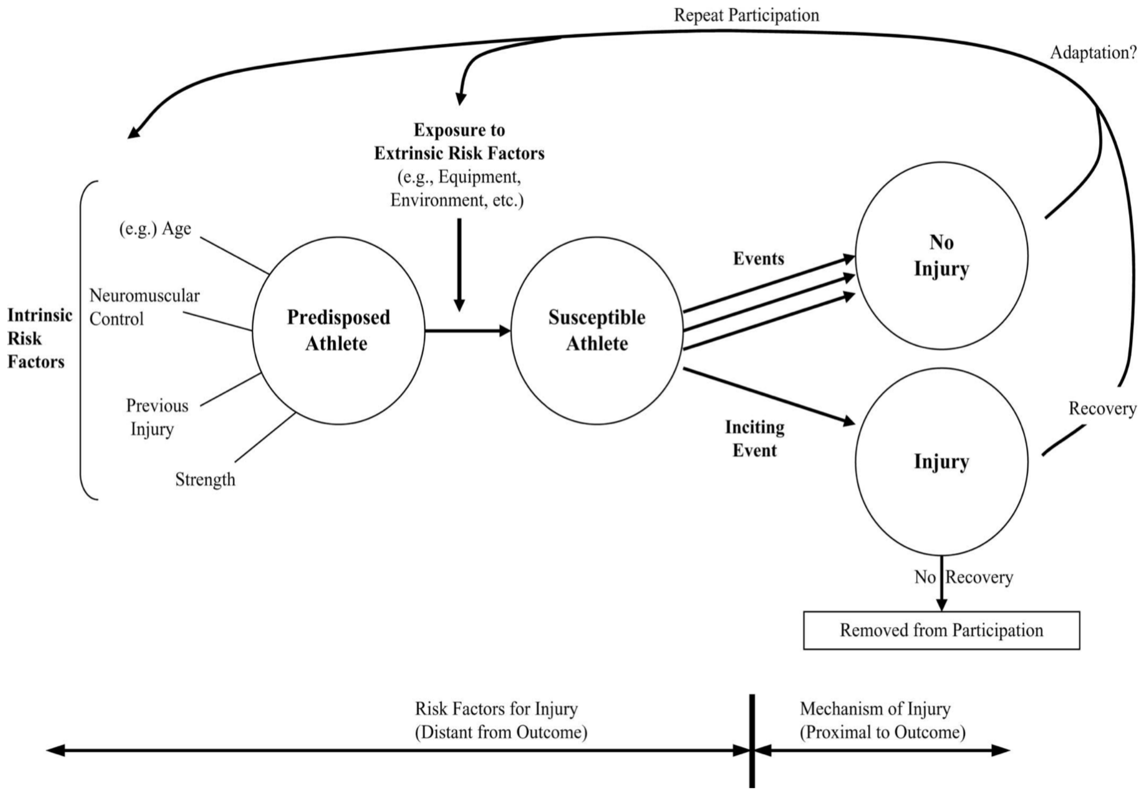

Figure 2. 5. A dynamic, recursive model of aetiology in sports injury (Meeuwisse et al., 2007).

2.4.1.2 Introduction to Screening

Screening is a technique used to identify risk factors for injury in participants who do not yet exhibit any signs or symptoms of that injury (Bahr 2016). In a risk factor screening, one screens individuals for exposures or characteristics that elevate the players' risk of sustaining an injury to inform management and potential intervention. Screening has predominantly been completed as a once-off, static snapshot at a particular time (predominantly preseason) (Verhagen et al., 2018). However, injury risk factors are dynamic and vary over time (Meeuwisse et al., 2007; Verhagen et al., 2018). Traditional methods of assessing a player's risk profile at a specific point in time, commonly during the preseason, may miss key injury risk factors. When these once-off screenings occur, neuromuscular capacities and sport-specific sports readiness are usually at their lowest points (Caldwell and Peters, 2009; Jensen et al., 2014). If we want to truly understand the aetiology of injury and develop effective prevention strategies, we need to look beyond the initial set of risk factors that are thought to precede an injury and consider how those risk factors have changed over previous cycles of participation, reacted with one another and whether or not they were associated with prior injury (Figure 2.6). A challenging area of sports injury research is determining the cause of injuries. In the context of sports, the dynamic, recursive nature of repeated exposure to different risk factors prior to injury has not gotten enough attention (Meeuwisse et al., 2007; Bittencourt et al., 2016; Windt and Gabbett, 2017). This has implications for injury prevention as well as how we approach study design and analysis. We must continue developing the methods we use to identify risk factors, such as continuous screening, and understand that risk factors for injury are complex, are always in a state of flux and interact differently, which is critical for injury prevention.

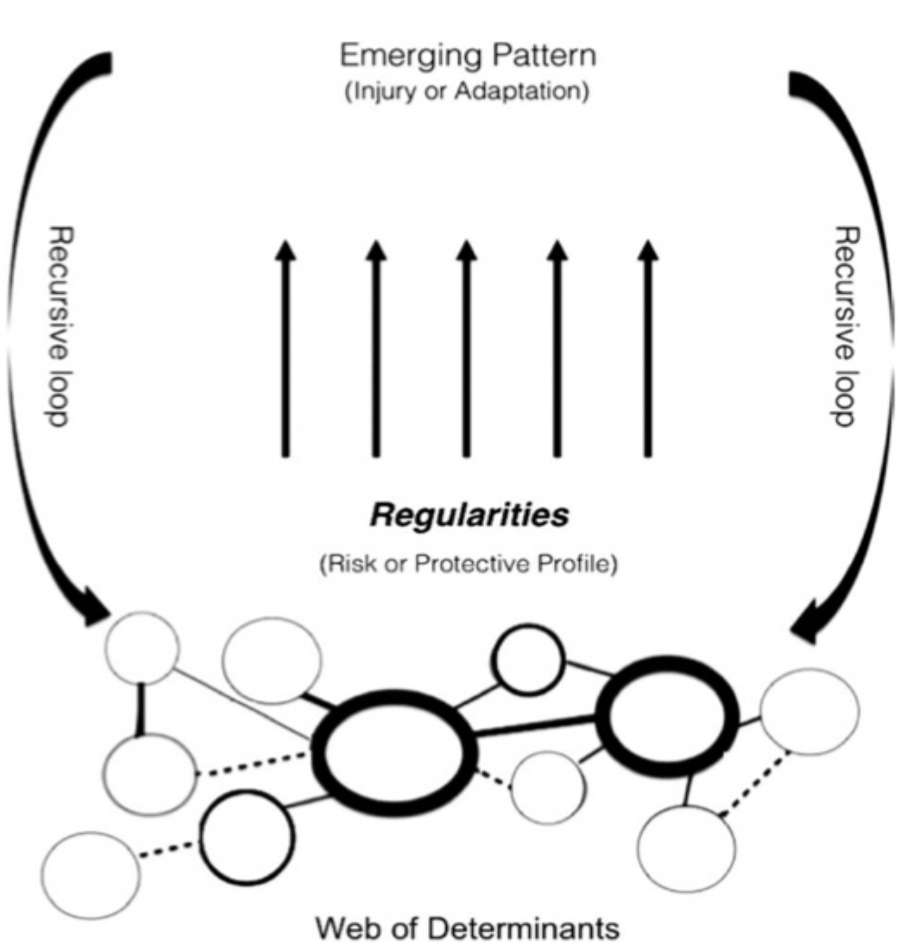

Figure 2. 6. A dynamic, recursive model of aetiology in sports injury (Meeuwisse et al., 2007).

2.4.2 Functional Anatomy of the Hamstrings

The hamstring muscle group comprises three muscles, semimembranosus, semitendinosus and biceps femoris (Figure 2.7), which can further be broken down into bicep femoris long head and bicep femoris short head. The short head of the hamstring muscle is uniarticular, crossing only through the knee joint, while the majority of the muscle group is biarticular and are primarily responsible for hip extension and knee flexion (Beltran et al., 2012). The hamstrings are situated in the thigh's posterior compartment. The biarticular nature of the hamstrings, which facilitates concurrent flexion of the knee and extension at the hip during running and kicking movements (Opar et al., 2012), makes the hamstrings susceptible to injury, which can be seen in the significant incidence and burden associated with hamstring injuries.

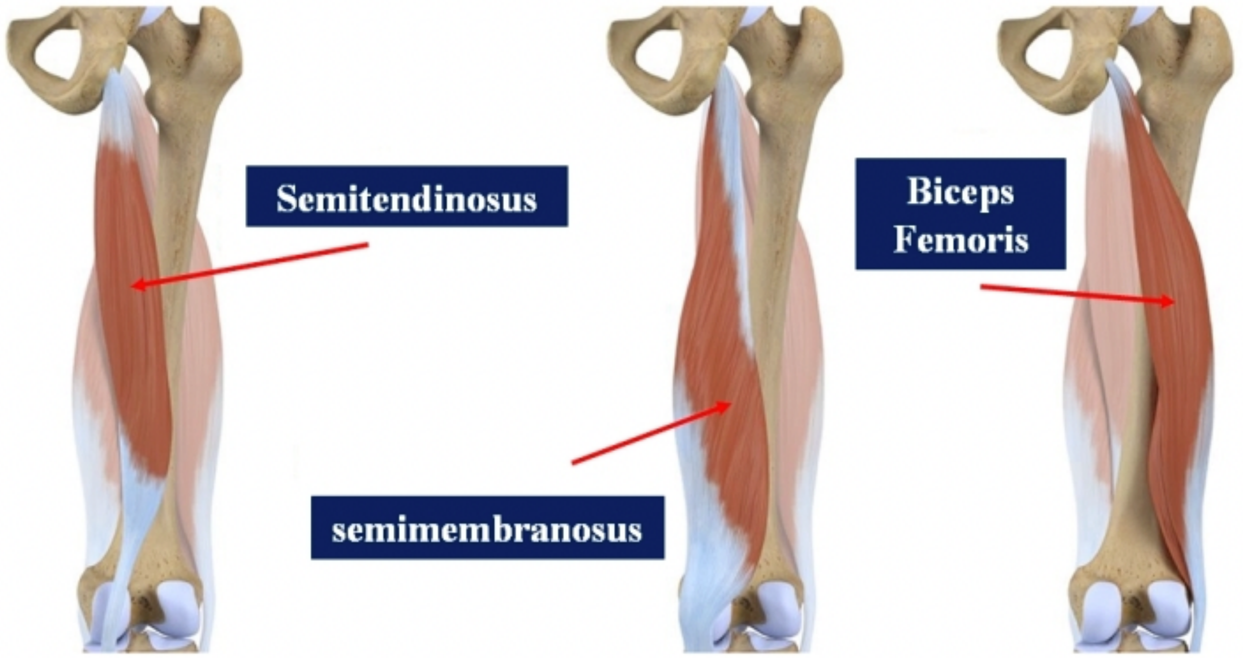

Figure 2. 7. A simple view of the Hamstring Muscle complex (Rodgers and Raja, 2023).

2.4.2.1 Semimembranosus

The semimembranosus has the largest volume and cross-sectional area of all the hamstring muscles (Woodley and Mercer, 2005). The semimembranosus has the longest proximal tendon of all the hamstring muscles (Woodley and Mercer, 2005), and it originates on the lateral facet or aspect of the ischial tuberosity (Woodley and Mercer, 2005; Sato et al., 2012; van der Made et al., 2015), anterior and lateral to the conjoined tendon of semitendinosus and bicep femoris long head (van der Made et al., 2015). Semimembranosus has an extra rectangular-shaped tendinous component that originates from the inferior surface of the ischium and is intimately connected with the adductor magnus in addition to its primary proximal tendon (Sato et al., 2012; Philippon et al., 2015). This tendinous structure is thought to dissipate the force from the primary semimembranosus tendon, which might explain why the semimembranosus is not injured as frequently as the bicep femoris or semitendinosus (Philippon et al., 2015).

As it descends, the semimembranosus tendon crosses medially, lying deep to the conjoined tendons of the bicep femoris long head and semitendinosus. The tendon rotates approximately 90° immediately distal to the ischial tuberosity (van der Made et al., 2015). The semimembranosus most proximal muscle fascicles emerge from the medial border of the proximal tendon at about mid-thigh level, much lower than the bicep femoris long head and semitendinosus (Storey et al., 2016).

The distal tendon of semimembranosus has up to 8 different attachment sites around the knee, including 1, a direct arm, 2, a lateral tendinous expansion off the main common tendon that contributed to the oblique popliteal ligament, 3, an attachment to the coronary ligament of the medial meniscus, 4, the oblique popliteal ligament, 5, a proximal posterior capsular arm, 6, a distal tibial expansion, 7, an anterior arm and 8, components of the posterior oblique ligament (LaPrade et al., 2007). Three attachment sites have been consistently agreed upon (LaPrade et al., 2007; De Maeseneer et al., 2014) (the direct arm, anterior arm and expansion to the oblique popliteal ligament); however, there is persisting uncertainty about others (De Maeseneer et al., 2014). The semimembranosus tendon bifurcates into a direct and anterior arm immediately distal to the joint line (LaPrade et al., 2007; De Maeseneer et al., 2014), although this division may not be apparent (De Maeseneer et al., 2014). The direct arm is developed from the main portion of the semimembranosus tendon. It runs distally to connect to a tubercle on the posterior side of the medial tibial condyle, commonly called the tuberculum tendinis (LaPrade et al., 2007). The anterior arm is a thick tendinous extension that begins immediately proximal to the direct arm's tibial attachment within the medial margin of the semimembranosus (LaPrade et al., 2007). It travels anteroinferior and connects to the medial tibial condyle about 1 cm distal to the joint line, deep to the proximal tibial insertion of the superficial medial collateral ligament (LaPrade et al., 2007). The medial side of the oblique popliteal ligament is formed by a thin, broad lateral extension of the semimembranosus tendon and the capsular arm of the posterior oblique ligament (LaPrade et al., 2007).

2.4.2.2 Semitendinosus

The semitendinosus is the hamstring muscle with the second lowest physiological cross-sectional surface area and volume. The proximal tendons of the bicep femoris long head and semitendinosus form a single "conjoined tendon" that arises from the ischial tuberosity's medial facet or posteromedial side (Woodley and Mercer, 2005; Sato et al., 2012). The semitendinosus is mainly muscular, and its origin on the ischial tuberosity is medial to the bicep femoris long head (Battermann et al. 2011; Woodley and Mercer 2005; Philippon et al. 2015).

As the conjoined tendon runs distally, muscle fascicles of the semitendinosus arise from the medial concave border (Woodley and Mercer, 2005). Approximately 9-10cm from their origin at the ischial tuberosity, the semitendinosus and the bicep femoris long head split (Philippon et al., 2015). The semitendinosus distal tendon is the longest of the hamstring muscles (Woodley and Mercer, 2005), lies superficial to the semimembranosus and is both long and thin in appearance. The semitendinosus travels medially over the knee joint to insert on the medial surface of the tibia, where the distal tendon and the distal tendons of the sartorius and gracilis contribute to the creation of the pes anserinus.

2.4.2.3 Biceps Femoris

2.3.2.3.1Bicep femoris long head

The bicep femoris long head’s thick, round tendon occupies the lateral half of the medial facet, and it has some connections to the sacrotuberous ligament (Woodley and Mercer, 2005; Philippon et al., 2015; Battermann et al., 2011). The bicep femoris long head has the second largest muscle belly volume and cross-sectional surface area of the hamstring muscles (Woodley and Mercer, 2005).

After separating from the semitendinosus, the tendon of the bicep femoris long head becomes intramuscular, developing a small, cordlike tendon on the muscle's medial surface with a flat aponeurotic expansion (Woodley and Mercer, 2005; Battermann et al., 2011). The architecture of the biceps femoris long head is pennate, with fascicles travelling between the proximal and distal tendon, covering approximately 60% of the muscle (Woodley and Mercer, 2005).

2.4.2.3.2 Bicep femoris short head

Bicep femoris short head has the smallest surface area of all the hamstring muscles but has the longest fascicles (Woodley and Mercer, 2005). The linea aspera of the femur, the lateral supracondylar ridge, and the lateral intramuscular septum are all origins of the bicep femoris short head (Woodley and Mercer, 2005). As it is the only hamstring muscle not to cross the hip joint, it does not aid in hip extension and only functions in flexing the knee.

2.4.2.3.3 Bicep femoris Distal End

Bicep femoris long head has the longest distal tendon of all the hamstrings, with a large, fan-shaped aponeurosis encompassing the lateral face of the bottom half of its muscle belly and some of the bicep femoris short head, generating a distal musculotendinous junction that spans around 40% of the muscle length (Woodley and Mercer, 2005). The fascicles from each head of the bicep femoris are oriented differently and meet at an angle of roughly 45° when they implant into the bicep femoris long head tendon (Woodley and Mercer, 2005). The long and short head of the bicep femoris together inserts onto the head of the fibula, lateral tibial condyle and fascia (Koulouris and Connell, 2005). It must also be noted that two distinct branches of the sciatic nerve, the tibial and common peroneal sections, respectively, innervate the long and short heads of the biceps femoris (Schache et al., 2010).

2.4.2.4 Function

Knee flexion, hip extension, and slight abduction of the lower extremity are the primary functions of the hamstring muscles as a whole, derived from their biarticular architecture (Stępień et al., 2019). The hamstrings contribute greatly to the swing portion of the gait cycle. They coordinate hip extension and prevent excessive knee extension by contracting eccentrically (Stępień et al., 2019). During knee extension, the hamstring muscle group work eccentrically to slow down the forward translation of the tibia along with the anterior cruciate ligament. These lengthening demands may predispose the hamstrings to strain injury because the lengthening may surpass the muscle's mechanical limitations (Chumanov et al., 2007). The bicep femoris long head consists of predominantly (51%) of type II which are classified as fast twitch (Dahmane et al., 2006), and given that fast glycolytic fibres have demonstrated a higher susceptibility for muscle damage during eccentric contraction in animal studies, this would be predicted to increase the likelihood of injury (Lieber and Fridén, 1988).

As each hamstring muscle has different attachment sites, each muscle contracts in a slightly different plane and direction depending on its anatomy. Due to the distal attachment, the bicep femoris provides stability to the posterolateral corner of the knee and when it contacts, causes external rotation of the tibia and the fibula (Terry and LaPrade 1996; Stępień et al., 2019). In contrast, due to their medial distal attachments, the semimembranosus and semitendinosus internally rotate the tibia when they contract (Terry and LaPrade, 1996; Stępień et al., 2019).

2.4.3 Inciting Event

There are at least two separate forms of acute hamstring strains, which are best characterised by the injury settings in which they occur (Askling et al., 2012). The most prevalent form of hamstring injury happens during high-speed running, whereas the other occurs during activities that cause substantial hamstring stretching or lengthening (Askling et al., 2012). The long head of the biceps femoris is usually injured during high-speed running, and the semimembranosus is commonly injured while stretching (Askling et al., 2008; 2007b; 2007a). Of the hamstring injuries in Gaelic football, 73.4% occurred while the player was sprinting, while only 4.4% occurred due to kicking (Roe et al., 2018**).** Similarly, 80-81% of hamstring injuries occurred during sprinting in AFL (the remaining 19% during kicking) (Hagel, 2005; Gabbe, 2005), 68% in rugby (Brooks et al., 2006) and 60-70% in professional English and European soccer (Woods et al., 2004; Ekstrand et al., 2012**).** However, sprint-related mechanisms of injury accounted for less than half (48%) of hamstring injuries in elite German soccer (Gronwald et al., 2021). Running as an inciting event was similar for both male (69.4%) and female (71.4%) collegiate soccer players for hamstring injury (Cross et al., 2013). Stretching, sliding, turning, twisting, kicking, overuse, and jumping are other hamstring injury mechanisms mentioned in the literature (Ekstrand et al., 2012; Woods et al., 2004). Although collectively, these activities are less frequent than sprint-related injuries, their significance should not be overlooked. Therefore it is critical to understand what mechanisms could be at play during the two most common types of injury. In either case, large muscle-tendon unit forces (active or passive), lengthening surpassing normal lengths, and high-velocity contractions are all plausible components of hamstring injury (Hickey et al., 2022).

2.4.3.1 Stretch-Related Hamstring Injury

A recent systematic review, including 26 studies, identified mechanisms of hamstring strain injuries (Danielsson et al., 2020). The systematic review included three studies investigating stretch-related hamstring injuries, with all studies reporting that hamstring injuries occur due to excess hip flexion and knee extension (Danielsson et al., 2020). A more recent study found that in stretch-related hamstring injuries, in both closed and open chain motions, the kinematic analysis of stretch-related injury patterns indicated a shift in movement direction from knee flexion to knee extension and a knee angle of less than 45° (Gronwald et al., 2021). Long muscle lengths appear to be where the stretch-type hamstring injury occurs (Heiderscheit et al., 2010). An uncontrolled stretch applied slowly or suddenly might result in this kind of injury. As previously mentioned kicking can be a mechanism for hamstring injuries (Roe et al., 2018; Hagel, 2005; Gronwald et al., 2021), which places the hamstrings in the stretch-type position of hip flexion and knee extension and similarly while picking the ball up off the ground while on the run (Worth, 1969). The semimembranosus muscle (87%) was predominantly affected by this stretch-type injury (Askling et al., 2008), which is essential for the clinician to know to inform the rehabilitation of the injured player. It is unclear whether high strain or stretch is sufficient enough to incite a hamstring injury on its own or if there is a potential interrelationship between strain and an eccentric contraction necessary for hamstring strain injury to occur (Opar et al., 2012).

2.4.3.2 High-speed Running-Related Hamstring Injuries

There is more conflicting evidence for the mechanism for high-speed running-related injuries than stretch-related injuries. During high-speed running, hamstring injuries occur when the lengthening demand on the hamstring muscle exceeds the tissue's mechanical limits while trying to decelerate the extending knee and flexing hip during the terminal swing phase (Chumanov et al., 2007). The large body of evidence from a systematic review which included 10 kinematic studies and 9 kinematic with electromyographic analysis studies, would suggest that excessive muscular strain generated by eccentric contraction during the late swing period of the running gait cycle is the most likely cause of hamstring injuries (Danielsson et al., 2020). Only three studies have looked at injuries in real-time, and all have identified that hamstring injuries occur during the terminal swing phase of running in real-time (Heiderscheit et al., 2005; Schache et al., 2009; 2010). This information was obtained by looking at the initial indications of injury, such as neuromuscular latencies (Heiderscheit et al., 2005; Schache et al., 2009), and by measuring the length, force, velocity, and negative work of the hamstring (Schache et al., 2010). During the late swing phase, the muscle-tendon units are at their longest, most vulnerable length, and the muscle is most heavily activated or producing its largest force (Chumanov et al., 2007; 2011), with the bicep femoris long head reaching 110% of its length in the terminal swing phase (Thelen et al., 2005). The bicep femoris long head experiences 2.2% and 3.3% greater strain than semimembranosus and semitendinosus during the terminal swing phase of high-speed running, respectively (Schache et al., 2012). The long head of the biceps femoris experiences the highest muscle-tendon unit stretch when running velocity increases from 80% to 100% of the maximum, and hamstring muscle force increases by around 1.3 times as a result (Chumanov et al., 2007). As a result, the peak strain experienced by the bicep femoris long head during terminal swing appears to be the characteristic that separates it from the other hamstring muscles and hence may be the most significant parameter for understanding why the bicep femoris long head is susceptible to injury during high-speed running in particular (Kenneally-Dabrowski et al., 2019). Even though sprinting and running are the most often reported causes of a hamstring injury, understanding other potential mechanisms is crucial information that may help reduce the risk of injury and create effective injury prevention strategies.

2.4.4 Categorization of Risk Factors

2.4.4.1 Intrinsic and extrinsic risk factors

In sports, risk factors for injury are any circumstances that may enhance or change a participant's risk of injury (Caine and Goodwin, 2016). Identifying risk factors that increase the players' risk for injury by effective screening may help reduce the incidence and burden of injury by targeting interventions at those with the greatest risk, highlighting the need to understand the aetiology and mechanisms of injury (Cameron, 2010). Risk factors for injury are typically categorised as either intrinsic or extrinsic (van Mechelen et al., 1992; Meeuwisse, 1994). Extrinsic risk factors are those that impact the player “from without” or external factors that are environment dependant including the sport, opposition, weather, coaching, surface conditions, rules, and equipment (Bahr and

Holme, 2003; Meeuwisse, 1994). Intrinsic risk factors are personal and internal to the player and include biomechanics, conditioning, range of motion, strength, age, sex, previous history, race and skill. However, the main goal of identifying risk factors that determine players' risk of injury are so that appropriate prevention strategies can be implemented to reduce this risk. Unfortunately, this traditional way of categorising risk factors into intrinsic and extrinsic risk factors gives the clinician little meaningful input into whether something can be implemented to intervene and minimise the contributory effect of any particular factor or combination of factors on subsequent injury (Cameron, 2010). Therefore reporting risk factors as modifiable and non-modifiable is an alternative and possible superior way of categorisation.

2.4.4.2 Modifiable and non-modifiable risk factors

According to Cameron (2010), Finch's TRIPP framework resonates with the concept of categorising risk factors into modifiable and non-modifiable risk factors (Finch, 2006; Cameron, 2010). The concept of modifiable and non-modifiable risk factors creates a basis that is more aligned with the primary goals of injury prevention, and it is used to design and evaluate the efficacy of prevention strategies (Cameron, 2010). From a clinical and injury prevention viewpoint, differentiating between modifiable and non-modifiable risk factors is critical for identifying and intervening. Modifiable risk factors are of particular interest as they provide the vector for developing injury prevention interventions that can alter a player's risk (Bahr and Holme, 2003). Non-modifiable risk variables may not be beneficial as intervention targets, but they are critical in identifying people at the highest risk for injury so that injury prevention measures can be focused on those who need it the most. As the most common and burdensome injuries in Gaelic games are hamstring injuries, the specific risk factors and mechanisms must be understood in order to develop specific injury prevention strategies.

2.4.5 Hamstring Risk Factors

Despite the abundance of research on hamstring strain injury risk factors, there is a paucity of evidence reporting consistent risk factors and how they interact (Buckthorpe et al., 2019). The high recurrence rates (Orchard and Best, 2002) and the fact that the rate of injury has been relatively stable with training injuries actually increasing over a period of years (Ekstrand et al., 2016) is a cause for concern. Only four non-modifiable risk factors were found to be significantly associated with a hamstring injury (age, previous history of hamstring strain, previous history of other lower limb injury (ankle, calf, knee injury), and playing position) (Table 2.9) based on one systematic review (van Beijsterveldt et al. 2013) and one meta-analysis (Green et al., 2020) (Table 2.8). These non-modifiable risk factors, unfortunately, cannot be altered. However, they are essential to understand so that interventions can be used to change the modifiable risk factors to decrease the risk of a hamstring injury. Non-modifiable risk factors such as eccentric hamstrings strength variables, fascicle length, and increased high-speed running distance (Table 2.10) (Green et al., 2020), were found to be significantly associated with a hamstring injury and may be monitored and targeted as part of injury prevention to decrease the risk of a hamstring injury.

Table 2. 8. Summary of Systematic Review/Meta-analysis of Risk Factors for Hamstring Injury.

Author & Year	Inclusion criteria	Number of studies included in systematic review/ meta-analysis	Number of hamstring injuries	Number of potential risk factors assessed
Green et al., 2020	Prospective design, evaluating risk factors hamstring injury and/or recurrent hamstring strain injury in athletic populations during sport	78 studies included. 71,324 participants aged 16–37	8,319 hamstring injuries. 967 recurrences	21
van Beijsterveldt et al., 2013	Prospective design involving risk factors for hamstring injuries in soccer. Statistical analysis includes non-injured and injured players in the region of the posterior thigh, sustained during a soccer training or match. Players age >18.	7 studies included. 1755 male, professional and amateur, outdoor soccer players	269 hamstring injuries	26

Table 2. 9. Non-modifiable Risk Factors for Hamstring Injuries Included in Systematic Reviews and Meta-analysis.

Author & Year	**Risk Factor**							
	Age	Height	Previous hamstring injury	Previous lower limb injury	Playing position soccer	Playing position American football	Playing position rugby	Playing position Gaelic football
Green et al., 2020	Older age SMD=1.6, 95%CI 0.6 to 2.6, *p*=0.002. LOE: strong (19 studies)	SMD=0.05, 95% CI -.02 to 0.01, *p*=0.42 LOE: strong (18 studies)	Previous hamstring injury RR=2.7, *p*=0.001. (14 studies) Previous hamstring injury within the same season RR=4.8, *p*=0.001. LOE: strong (4 studies)	ACL RR=1.7, *p*=0.002. (2 studies) Knee LOE: moderate. (2 studies) Calf RR=1.5, *p*=0.001. (4 studies) Ankle LOE: limited. (1 study) Other injury no association. LOE: strong	Associated with risk of hamstring injury (LOE: strong) (10 studies)	Associated with risk of hamstring injury (LOE: moderate) (2 studies)	Associated with risk of hamstring injury (LOE: moderate) (2 studies)	Associated with risk of hamstring s injury (LOE: limited) (1 study)
van Beijsterveldt et al., 2013	Significantly older (3 of 4 studies)	No association (4 studies)	Significant risk factor (3 studies)	-	No association (1 study)	-	-	-

SMD: standardised mean difference; RR: risk ratio; LOE: level of evidence; %: percentage; CI; confidence interval; p; p value significant at $p<0.05$

2.4.5.1 Non-modifiable Risk Factors for Hamstring Injury

2.4.5.1.1 Age

Increasing age (Table 2.9) is a major non-modifiable risk factor for a hamstring injury that is easy to assess and may be utilised to determine demographic subgroups at risk (van Beijsterveldt et al., 2013; Freckleton and Pizzari, 2012; Green et al., 2020). In a meta-analysis of 19 studies, older age was the strongest associated risk factor for hamstring injury (SMD=1.6, p=.002) (Green et al., 2020). However, in Gaelic footballers, age as a risk factor is more nuanced as players aged between 18-20 and over 30 had an injury rate ratio (IRR) of 2.3 (Roe et al., 2018). In contrast, players aged between 21-24 (IRR=0.5) and 25-29 (IRR=0.9) were at decreased risk of a hamstring injury respectively. The risk is greatest for players transitioning in (younger ages between 18 and 20) and out (older players greater than 30 years of age) of elite Gaelic football teams, according to this U-shaped pattern (Roe et al., 2018). The younger group may be at increased risk of a hamstring injury while adjusting to the increasing demands of more intense or high levels of play. At the same time, the older Gaelic footballer may be at greater risk due to the accumulation of loads over a number of seasons (Roe et al., 2018). In soccer, it was found that players that sustained a hamstring injury were significantly older than players that did (Arnason et al., 2004). In fact, older premier league soccer players were 1.78 times more likely to sustain a hamstring injury than younger players (Henderson et al., 2010). Similarly, in Australian rules football, players over the age of 23 were 1.37 times more likely to sustain a hamstring injury, and players with over 7 years of experience have significantly higher incidence rates than less experienced players (Orchard, 2001; Rogalski et al., 2013).

Players that are older may have an increased risk as they may have had a previous injury, and age may influence injury risk because it correlates with exposure: as players get older, they have been exposed to more mechanical stresses than younger players, increasing their chances of encountering injury mechanisms (Green et al., 2020). Ageing results in a progressive deterioration in physical performance over time (Green et al.,2020). Performance capacities such as speed and strength have been shown to decrease due to ageing (Keller and Engelhardt, 2013; Korhonen et al., 2003). A decrease in speed as age increases results from shorter stride length and increased ground contact time (Korhonenet al., 2003). As a player ages, muscle fibre numbers decrease, and in turn muscle fibre loss lowers strength, slows muscular metabolism, and thus raises the risk of muscle injury (Zatsiorsky and Kreamer, 2008). However, this may not affect the athletic population as studies have been in an older population. As a result of decreased athletic capacities, if older players are less able to cope with sports demands and have altered neuromuscular control, they may be at a higher risk of injury. Although age is a non-modifiable risk factor and cannot be altered, it is an important factor in categorising players and to be able to support our players in managing risk and, as a result, increased participation and performance.

2.4.5.1.2 Previous Hamstring Injury

A history of previous injury is the strongest indicator of the future risk of musculoskeletal injury (Bahr, 2016) and has been identified as a risk factor for subsequent hamstring injury across the literature (Table 2.9) (van Beijsterveldt et al., 2013; Freckleton and Pizzari, 2012; Green et al., 2020). The recent meta-analysis found that a previous hamstring had a risk ratio of 2.7 for a subsequent hamstring injury and was even more significant for a recent previous hamstring injury (within the same season) RR=4.8 (Green et al., 2020). Specifically, in elite Gaelic football, 44% of players that sustained a hamstring injury received a subsequent hamstring injury, with a risk ratio of 3.3 (Roe et al., 2018). Hamstring re-injury rates range from 13.9–63.3% and generally occur in the exact location of the initial hamstring injury (Wangensteen et al., 2016; de Visser et al., 2012). Re-injury occurs a median time of 19 days after return to sport from the initial injury, with 50% of re-injuries occurring within 25 days of return, and players have a 9% risk of being injured again within a week of returning to games (Wangensteen et al., 2016; de Visser et al., 2011). Similarly, in male Gaelic football, 39% of re-injuries occur within eight weeks of the initial injury (Roe et al., 2018). When re-injury occurs, almost 3 in every 4 injuries are as severe or more severe than the initial injury, highlighting the need for comprehensive rehabilitation (Wangensteen et al., 2016). Secondary injury prevention methods aim to identify the injury of interest early enough that intervention can prevent it from progressing or getting worse (Drew et al., 2016). Similarly, tertiary injury prevention methods aim to minimise complications and any long-term effects of an injury during rehabilitation, including future sports injuries or extended absence from the sport. This high rate of re-injury raises the possibility that players are returning to sports too soon with a lack of adequate rehabilitation (Erickson and Sherry, 2017) and that, as clinicians, we are failing in both secondary and tertiary injury prevention.

The underlying causes of previous hamstring injury history and its association with subsequent hamstring injury are not fully understood. However, structural maladaptations exist, such as reduced bicep femoris fascicle length (Timmins et al., 2016), decreased flexibility (Fyfe et al., 2013), muscle atrophy (Sanfilippo et al., 2013; Fyfe et al., 2013) and formation of inelastic scar tissue (Silder et al., 2008; Fyfe et al., 2013) occur after a previous muscle injury. Similarly, previous injury affects the structure and function of the hamstrings as shown on testing of the eccentric Nordic hamstring exercise and isokinetic testing of previously injured bicep femoris muscles, with long-term impairments in voluntary activation have been noted (Avrillon et al., 2020; Bourne et al., 2016; Opar et al., 2013). Moreover, previously damaged bicep femoris long head muscles had lower surface EMG activity than contralateral uninjured muscles in the late swing phase of running (Higashihara et al., 2019). During sprinting, players demonstrate a variety of posterior thigh activation patterns, and after recovering from a bicep femoris long head injury, they may show an altered intramuscular hamstring activation (Bourne et al., 2021). These deficiencies after injury may impair the hamstrings' capacity to withstand high levels of stress and strain, increasing the chance of recurrence (Green et al., 2020). Alternatively, players may return to their sport too soon after the initial injury, while a muscle injury's biological healing is incomplete or muscle function is not fully recovered (Wangensteen et al., 2016). The high re-injury rate in Gaelic football suggests that rehabilitation may be inadequate, players are given insufficient time for healing, and the factors that lead to injury have not been addressed (Roe et al., 2018). Several implications include player unavailability due to high injury and re-injury rates affecting team performance in rugby and soccer, leading to less successful campaigns (Williams et al., 2016; Hägglund et al., 2013). As described by the dynamic recursive model (Meeuwisse et al., 2007), a player's injury risk may alter with each exposure, and risk factors can interact in many ways (Bittencourt et al., 2016). Therefore players with a previous hamstring injury should first be identified and screened for any remaining risk factors such as eccentric strength, strength imbalance, reduced range of motion etc., which should subsequently be the focus of rehabilitation and clinical management. If this predisposing condition is not addressed, the player will continue to be at risk for subsequent hamstring injury despite adequate healing or regaining tissue capacity (Opar et al., 2012). If re-injury occurs, it is essential to identify the determinants related to the re-injury so that a more cautious rehabilitation regimen and better timing for returning to sports might be beneficial (de Visser et al., 2011). However, screening/monitoring the previously injured player will help identify other risk factors that can be worked on using injury prevention strategies to mitigate the risk of future injury.

2.4.5.1.3 Previous Lower Limb Injury

Specific injuries to the lower limb, such as knee, ankle, and calf injuries, have been shown to increase the risk of sustaining a hamstring injury (Freckleton and Pizzari, 2012; Green et al., 2020). A previous ACL injury has a risk ratio of 1.7 for subsequent hamstring injury (Green et al., 2020). The exact mechanisms are unknown, but it may be a result of reduced proprioception, strength deficits and altered gait associated with ACL injuries (Green et al., 2020) or due to deficits in strength and the cross-sectional area within the hamstrings after harvest of a hamstring graft if used for the ACL reconstruction (Messer et al., 2020; Bourne et al., 2019). A previous calf injury may increase the risk of sustaining a hamstring injury by 50% (Green et al., 2020). Calf injuries have been shown to have a risk ratio between 1.3-1.58 for a subsequent hamstring injury and as high as 8.94 if the calf injury has occurred in the previous eight weeks (Timmins et al., 2015; Bourne et al., 2015; Orchard et al., 2012; Orchard, 2001). The soleus and gastrocnemius muscles are extremely important in high-speed running (Hamner and Delp, 2013), and deficits in the calf muscle may put increased demands on the hamstring during high-speed running, which may put the hamstrings at increased risk of injury. During the late swing phase, the gastrocnemius calf muscle, which is also a knee flexor, has been found to have a role in absorbing energy in the form of an eccentric contraction (Schache et al., 2010). The gastrocnemius knee flexion moment is greatest near full knee extension (Li et al., 2002), a position similar to the knee in the late swing phase. Therefore the hamstrings may have to compensate for a reduced eccentric capacity of the calf musculature after injury. A possible explanation for the increased risk of hamstring injuries after ankle and calf injuries may be due to altered biomechanics and gait, which may lead to an increasing dependence on more proximal structures, such as the hamstrings, to absorb impact forces due to these changes (Doherty et al., 2015). This highlights the importance of rehabilitating injuries appropriately and identifying and addressing the factors predisposing the player to injury.

2.4.5.1.4 Playing position

Playing position has been identified as a risk factor for a hamstring injury with limited to strong evidence across a range of sports (Table 2.9) (Green et al., 2020). Positions with the greatest running demands have the greatest risk of hamstring injury across a range of sports (Green et al., 2020). In the Gaelic games context, only one study has examined the association between playing position and hamstring injury risk (Roe et al., 2018). Defenders (RR=1.96) and midfielders (RR=1.45) had a greater risk of sustaining a hamstring injury than forwards (RR=0.33) (Roe et al., 2018). Roe et al. (2018) suggests that this may be due to the physical demands in the position as defenders (22.5 m/min) and midfielders (31.8 m/min) cover more high-speed running distance (17 km/h) than forwards (18.2m/min) (Malone et al., 2016). Similarly, in Australian rules footballers, 38-50% of all hamstring injuries occur to the player playing in the midfield position, which requires a lot of high-speed running, and they cover 17% greater distance per minute than other positions (Opar et al., 2015; Ruddy et al., 2018; Wisbey et al., 2010). Therefore, the relationship between playing position and hamstring injury risk is likely due to running volume in different positions.

To conclude, age and previous hamstring injury are powerful non-modifiable risk factors for a hamstring injury. Other vital risk factors for injury include other lower limb injuries and playing position, which may be related to other risk factors, demonstrating the complexity of hamstring risk factors. Although these non-modifiable risk factors cannot be altered directly, understanding them for hamstring strain injury is critical for creating risk profiles, developing prevention and rehabilitation strategies and targeting the interventions in those that need them most. Deficits due to age or previous injury need to be screened for in older and previously injured players. The U-shape age risk factor identified by Roe et al. (2018) would suggest that younger players must also be assessed/screened. The players in high-risk profiles based on non-modifiable risk factors could lower their risk of injury by addressing some modifiable risk factors with specific interventions.

2.4.5.2 Modifiable Risk Factors for Hamstring Injury

2.4.5.2.1 Fatigue

Fatigue and its associated performance reductions have frequently been suggested as risk factors for injury (Green et al., 2020; Opar et al., 2012; Mair et al., 1996; Worrell and Perrin, 1992). Fatigue is characterised as a reduced ability of producing the required performance output, which limits both physical and mental abilities (Alba-Jiménez et al., 2022). As previously mentioned, it's unclear if hamstring strain results from a single incident that exceeds the limits of the muscle's extensibility and contractility or from a build-up of eccentric contractions throughout numerous maximal sprints that results in neuromuscular fatigue (Opar et al., 2012; Baumert et al., 2021). Acute and chronic muscle function impairment are caused by neuromuscular fatigue (Byrne et al., 2004). Although, the association has not been investigated in Gaelic games, after a simulated soccer game, significant reductions (16–20%) in hamstring muscle strength have been observed (Matinlauri et al., 2019; Delextrat et al., 2018). Similarly, after repeated fatiguing sprint exposures, isometric hamstring strength was significantly lower than pre-event, immediately post-event and 48 hours post (Baumert et al., 2021). Likewise, fatigue affects movement patterns and neuromuscular control with decreased peak knee extension during the late swing phase at post-intervention (− 10.9%) compared to pre ($p = 0.047$) (Baumert et al., 2021) and during a soccer match maximal hip flexion significantly reduced ($p<0.01$) (Small et al., 2009) which indicates reduced hamstring length or that fatigue may cause the pelvis to tilt more anteriorly, putting more strain on the hamstrings. These changes in knee and hip joint positions imply that proprioception may change due to fatigue from dynamic exercise (Allen et al., 2010). Increased high-speed running, discussed in more detail in section 2.4.5.2.4, is a risk factor for hamstring injuries in AFL. This could be due to players experiencing more significant fatigue or a lack of conditioning. Given the aforementioned considerations, fatigue may significantly contribute to the pathogenesis of hamstring injury by impairing other aetiologically modifiable risk factors.

2.4.5.2.2 Hamstring Strength

As previously mentioned, a substantial amount of hamstring injuries occur during sprinting, where the hamstrings must provide an eccentric contraction as a "breaking force" to slow knee extension during the terminal swing phase, and decreased eccentric hamstring strength can be assumed to be a risk factor for a hamstring injury. Eccentric strength is one of the many modifiable risk factors that may be associated with the risk of hamstring injury (Table 2.10). Studies have assessed different eccentric strength variables as risk factors for hamstring injury using various methods, including isokinetic machines, externally fixed dynamometers such as the NordBord and Hamstring Solo Elite, or by using a handheld dynamometer (Green et al., 2020). Eccentric hamstring strength can be assessed in many ways.

Table 2. 10. Modifiable Risk Factors Included in Systematic Reviews (Green et al., 2020; van Beijsterveldt et al., 2013) and Meta-analysis (Green et al., 2020).

Risk Factor	**Author & Year**	
	Green et al., 2020	van Beijsterveldt et al., 2013
Weight	SMD=0.39, 95%CI -0.29 to 1.0, *p*=0.26 (18 studies)	No association (4 studies)
Body mass index	SMD=0.43, 95%CI -0.51 to 1.38, *p*=0.30 (9 studies)	No association (3 studies)
Muscle size	Biceps femoris, gluteus maximus, gluteus medius size, no association LOE: limited	-
Fascicle length	Association LOE: limited	-
Muscle-tendon unit stiffness	Association LOE: limited	-
Strength - endurance	Association LOE: limited	-
Strength - imbalance	Association LOE: strong	No association (1 study), association (1 study)
Strength - Nordic hamstring test (absolute force)	SMD=.31, 95%CI -.97 to 0.4, *p*=0.13, association (LOE: low)	No association (1 study)
Strength - Nordic hamstring test (force relative to body mass)	SMD=.34, 95%CI -1.1 to 0.4, *p*=0.14, association LOE: low	-
Strength - isokinetic knee flexor	Association LOE: strong	-
Strength - isokinetic strength ratios	Association LOE: strong	-
Single leg hop for distance	Association LOE: limited	-
CMJ height	Association LOE: strong	No association (3 studies)
CMJ power output	Association LOE: moderate	No association (1 study)
% difference between nonCMJ and CMJ	Association LOE: limited	-
Flexibility	-	No association (3 studies), association (1 study)
Passive knee extension	No association LOE: strong	-
Active knee extension	No association LOE: strong	-

Passive straight leg raise	No association LOE: strong	-
Slump	No association LOE: moderate	-
Modified thomas test	Conflicting	-
Knee to wall	Conflicting	-
High-speed running exposure	Association LOE: limited	-
YOYO	No association LOE: moderate	No association (1 study)

SMD: standardised mean difference; LOE = level of evidence; CMJ: countermovement jump; CI: confidence interval; p: p value significant at $p<0.05$.

2.4.5.2.2.1 Isokinetic testing

Testing eccentric strength of the hamstrings has traditionally been completed in a lab-based setting using an isokinetic machine which has been described as the gold standard for testing (Harding et al., 2017). A recent meta-analysis that only assessed the predictive effectiveness of isokinetic strength testing to determine the risk of future hamstring injury indicated that only two variables of eccentric strength were associated with injury (Green et al., 2018). The meta-analyses revealed a small, significant predictive effect for absolute (SMD=−0.16, p =0.04, 95% CI −0.31 to −0.01) and relative (SMD=−0.17, p =0.03, 95% CI −0.33 to −0.014) eccentric knee flexor strength (60°/s) and the risk of hamstring injury (Green et al., 2018). In a single study of professional soccer players, eccentric hamstring strength asymmetries (i.e. one leg being weaker than the other) measured using an isokinetic machine were shown to have the highest odds ratio of future hamstring injury (OR= 3.88; 95% CI, 1.13-13.23; p = .03) (Fousekis et al., 2011). However, no information was provided on the precise isokinetic velocities used in this study. One study on sprinters showed that peak torque for the hamstring contracting eccentrically was significantly lower in the injured lower limb (2.17 Nm/kg) than in the uninjured lower limb (2.37Nm/kg) (p=0.03) (Sugiura et al., 2008). Similarly, decreased eccentric strength (60°/s) on the isokinetic test was a risk factor for injury in soccer players (OR= 1.37; 95% CI, 1.01-1.85; p = .04) (van Dyk et al., 2016).

There is conflicting evidence to suggest that strength imbalance is a risk factor for hamstring strain injury. Between-limb imbalance is the ratio of the hamstring muscles on either limb (left to right ratio or dominant limb to non-dominant limb ratio). No significant association was found between-limb imbalance and hamstring injury with any of the strength ratios at speeds of either 180°/s or 60°/s examined using isokinetic strength tests (Green et al., 2018). However, it was not a risk factor in Australian rules football (Bennell et al., 1998). Possible explanations for the discrepancy in results may be due to testing procedures and speeds. Absolute and relative eccentric knee flexor weakness at 60° per second has the best predictive ability when using isokinetic (Green et al., 2018). Due to impracticalities associated with isokinetic dynamometry's limited ability to detect hamstring injuries, its cost, being lab-based, the time of each test and specialised training required for isokinetic strength testing that the use of isokinetic may need to be reconsidered, and alternative methods of testing should be explored (Green et al., 2018; Lodge et al., 2020).

2.4.5.2.2.2 Fixed dynamometry testing

Measuring the eccentric strength using the Nordic hamstring exercise on fixed dynamometers has gained popularity due to the quick, efficient real-time feedback data and portability (Lodge et al., 2020). Both the NordBord (ICC = 0.85-0.89) (Opar et al., 2013) and the Hamstring Solo Elite (ICC = 0.910-0.914) (Lodge et al., 2020) had good test-retest reliability. A recent meta-analysis including six prospective studies investigating eccentric strength as a risk factor for hamstring injury found that absolute eccentric hamstring strength was not significantly different between players that sustained and did not sustain an injury (SMD = − 0.22, p =0.02, 95% CI = − 0.50 to 0.05) (Opar et al., 2021). Of those six studies, two found that decreased absolute eccentric strength identified using the Nordic hamstring exercise was associated with the risk of hamstring injury (Table 2.11) (Opar et al., 2015; Timmins et al., 2016). The study by Timmins et al. (2016) found that those with absolute eccentric hamstring strength below 337N (measured using a NordBord) were at a 4.4 times higher risk of sustaining a hamstring injury. Similarly, Australian rules players with eccentric hamstring strength below 256N (measured using the NordBord) were 2.7 times more likely to suffer a hamstring injury (Opar et al., 2015). However, the meta-analysis cannot conclusively state that there are no variations in absolute eccentric strength between players that became injured and uninjured players due to low sample sizes, but rather that any variations if they do exist, are likely to be small (Opar et al., 2021). This indicates that the evidence may not be as conclusive. Therefore, further research is needed in this area and specific to the Gaelic games context. Furthermore, a single test occasion may not be sufficient; hence it is essential that it is tested on multiple occasions, as eccentric strength can fluctuate, and risk factors are dynamic and change with every exposure (Meeuwisse et al., 2007; Windt and Gabbett, 2017).

It has been argued that absolute strength is inherently flawed due to a failure to account for differences in body mass across individuals (Buchheit et al., 2016). Evidence shows that older, heavier players outperform lighter players in absolute eccentric strength (Buchheit et al., 2016). Six studies looked at eccentric knee flexor strength normalised to body mass. However, when body mass was accounted for, the meta-analysis concluded that relative eccentric hamstring strength was not a risk factor for subsequent hamstring injury (SMD = −0.23, 95% CI = −0.55 to 0.10) (Opar et al., 2021). One study found that eccentric knee flexor strength normalised to body mass less than 4.35 N/kg had an OR=2.5 (p=0.04) (Timmins et al., 2016). One study found that chronological age enhanced the absolute strength demonstrated during the Nordic hamstring exercise in adolescent male players. However, these strengths are relatively consistent when normalised to body mass and similar to adults (Jeanguyot et al., 2023). Although eccentric knee flexor strength normalised to body mass has not been identified as a risk factor, this information is critical as it can inform physical preparation as youth players transition onto senior teams and act as a benchmark for rehabilitating hamstring injuries. Previous studies have also used team means for body mass in calculating eccentric strength relative to body mass, which may not adequately reflect the underlying significance of relative strength as a risk factor for a hamstring injury. Therefore body mass must be individualised for the calculation of relative strength.

Between-limb imbalances highlight the extent of the strength discrepancy between the limbs. The meta-analysis concluded that between-limb imbalance was not a risk factor for hamstring injury (SMD = 0.01, 95%CI = − 0.24 to 0.25) (Opar et al., 2021). Four studies investigating limb imbalance as a risk factor for hamstring injury using the Nordic hamstring exercise test found no significant results (Timmins et al., 2015; Opar et al., 2015; van Dyk et al., 2017; Roe et al., 2020). However, Bourne et al. (2015) used the Nordic hamstring exercise test using the NordBord to assess eccentric hamstring strength in rugby union players and players who had a between-limb eccentric hamstring strength imbalance of ≥15% and ≥20% were 2.4 times and 3.4 times more at risk of sustaining a subsequent hamstring injury. In Gaelic football, Roe et al. (2020) found that players that sustained hamstring injury had a significantly lower strength imbalance than players that did not sustain a hamstring injury (Table 2.11). This is an unusual finding, but the study had a short follow-up time, so further research is needed on this population. Large imbalances or asymmetries could lead to less effective muscular activity or biomechanics and may signal that one limb is less capable of fulfilling work demands or coping with the stressors that players face, leading to an increased risk for injury (Heiderscheit et al., 2010). Asymmetries may affect running biomechanics, causing variable loads to occur throughout the hamstrings, which might account for a higher risk of hamstring injuries (Lee et al., 2009). Leg length discrepancy, history of injuries, and sports demands all contribute to asymmetries (Bishop et al., 2016)

Despite the results of the meta-analysis not supporting the use of the Nordic hamstring test to identify hamstring injury risk, the use of the Nordic hamstring exercise greatly reduces injury risk (van Dyk et al., 2019) and therefore, further research is warranted. The meta-analysis included different sports, each with different sporting demands and individual player values for the Gaelic games population is needed. There are many limitations to the previous research. Firstly, only six studies were included in the meta-analysis, and the follow-up time was short (3-10 months). Much of the research so far has been carried out at preseason, often when a player could be in their worst conditioning due to the effect of detraining, and strength levels fluctuate at different times of the season and can interact with other risk factors such as high-speed running distance. Therefore, testing should be continuous across a season at many time points, as risk factors can alter throughout the season. Eccentric strength relative to body mass was calculated using mean scores for body mass, which may not accurately evaluate the true importance of relative strength as a risk factor for hamstring injuries as it is not specific to that player. Therefore, a more complete study encompassing individual data points may be required to establish the usefulness of normalising knee flexor strength to mass using the Nordic hamstring test (Opar et al., 2021). Between-limb imbalance should not be neglected, as differences in eccentric knee flexor strength between the legs may affect running biomechanics or limit the ability of the weaker leg to decelerate the forward swinging shank during the terminal swing, which may put players at risk of injury (Opar et al., 2012). Also, there has previously been no standardisation of foot position, which has yielded different results on the Nordic hamstring exercise, with greater force being produced on the test with the ankle in a plantarflexed position (Nishida et al., 2021).

Therefore when evaluating maximal eccentric strength during the Nordic hamstring test using the NordBord or Hamstring Solo Elite, the location of the ankle should be carefully considered. As a result of the many limitations in previous studies and the need for continuous monitoring, further research is warranted in this area.

Table 2. 11. Eccentric Hamstring Strength as Measured by the Nordic Hamstring Exercise.

Author & Year	**Participants/ Sport**	**Method**	**Main findings**
Bourne et al., 2015	158 uninjured 20 injured 23 ± 4 years Rugby	3 reps measuring peak force during pre-season, follow up 6 months.	Eccentric knee flexor imbalance ≥15% and ≥20% ↑ risk 2.4-fold (*p*=.033) and 3.4-fold (*p*=.003), respectively. Every 10% ↑ in between-limb imbalance, ↑ risk 1.34 (*p*=.028) 2-limb–average eccentric knee flexor strength <267.9N RR0.17; *p* = .204 Normalised strength < 3.18 N/kg, RR, 0.97 ; *p* = .957.
Opar et al., 2015	159 uninjured / 27 injured 23 ± 4 years AFL	3 reps measuring average peak force at the start of pre-season, follow up 10 months.	Absolute strength < 256N (preseason) RR=2.7 (*p* = 0.006) and <279N (end of the preseason) RR= 4.3 (*p* = 0.002). Every 10-N ↑eccentric knee flexor strength, the risk of injury ↓ 6.3% (early preseason) and 8.9% (late preseason)
Roe et al., 2020	156 uninjured 28 injured 27 ± 3 years Gaelic Football	3 reps measuring average peak force during pre-season, follow 3 months.	Between-limb imbalance greater in uninjured group = (9.1%) than injured group (5.1%) (*p* =.001). No other differences were found between groups.
Ruddy et al., 2018	150 uninjured 26 injured 25 ± 3 years AFL	3 reps measuring average peak force at the start of pre-season, follow up10 months.	2013 - Average eccentric hamstring strength lower in injured (260N) vs uninjured (301N) Between-limb imbalance was similar in injured (45) vs uninjured (49N) 2015 - Average eccentric hamstring strength was similar for injured (341N) and uninjured (341N) between-limb imbalance was similar for injured (30N) and uninjured players (34N)
Timmins et al., 2016	105 uninjured 26 injured 25 ± 5 years Soccer	3 reps measuring average peak force at the start of pre-season, follow up 10 months.	Injured limbs were weaker (260.6N) than the two-limb-average of uninjured players (309.5N) (mean difference: 48.9 N; *p* =0.004). Eccentric strength knee flexor torque (115.2 Nm±37.1), weaker than two limb average in injured than of uninjured players (135.5 Nm±33.7) (mean difference: 20.3 Nm; *p* =0.008). Absolute eccentric strength <337N RR=4.4 (*p* =0.013)

			Eccentric strength relative to body mass <4.35N/kg RR= 2.5 (*p* =0.041)
van Dyk et al., 2017	216 uninjured 29 injured 26 ± 5 years Soccer	Set x 3 reps measuring peak and average peak force during pre-season, follow up 10 months.	No significant differences were found for any variables.

RR: risk ratio; OR: odds ratio; N: newtons: N/kg: newtons per kilogram: reps: repetitions; AFL: Australian football league; p: p value significant at $p<0.05$.

2.4.5.2.3 Fascicle Length

There is limited research available to suggest that short bicep femoris long-head fascicle length is associated with the risk of hamstring injury (Green et al., 2020). It was found retrospectively that the biceps femoris long head fascicle lengths were significantly different in the injured and uninjured limb of players and that fascicle length relative to muscle thickness was less in the injured compared to the uninjured (Timmins et al., 2014). However, as the research is retrospective, it is impossible to tell if these variations in fascicle length increased the risk of a hamstring injury or were a consequence of the initial injury. A meta-analysis investigating hamstring muscle architecture in previously injured players revealed that in comparison to controls, biceps femoris long head fascicle was substantially lower in players with a previous hamstring injury (SMD = 0.57; 95% CI: 0.92 to 0.22; p = 0.0015) (Kellis and Sahinis, 2022). Timmins et al. (2016) found that biceps femoris long-head fascicle lengths shorter than 10.56 cm (RR=4.1; 95% CI 1.9 to 8.7) significantly increased the risk of a hamstring strain injury. Similarly, in Australian rules football, shorter fascicles increased the risk of hamstring injury (RR=1.89; 95% CI 1.20 to 2.99) (Opar et al., 2022). Using the results of Timmins et al. (2016) (10.56cm), one study on male soccer players found that players who had previously been injured had biceps femoris long head fascicles shorter than that reference in both lower limbs. In contrast, the control group's average value was >1 cm longer (de Lima-E-Silva et al., 2020). However, using these cut-off points derived from soccer, the risk of a hamstring injury was not associated with the length of the biceps femoris long head fascicle, with Australian football players who had fascicles shorter than 10.56 cm experiencing the same amount of risk (RR=1.1) as those who had larger biceps femoris long head fascicles (Lee Dow et al., 2021). Fascicle length relative to biceps femoris long head length total length <0.25 presents a 3.7 higher risk of sustaining a hamstring strain injury during the season than those with ≥0.25 relative fascicle length (Timmins et al., 2016). Similarly, smaller relative fascicle length (≤3.82; RR=1.78; 95% CI 1.15 to 2.75) when measured at preseason was linked to a higher risk of hamstring injuries (Opar et al., 2022). Therefore the evidence would suggest that shorter bicep femoris fascicle length and short fascicles relative to biceps femoris long-head length total length are risk factors for a hamstring injury.

The reasoning for the association between shorter fascicle length and hamstring injury risk has yet to be determined. However, it is proposed that shorter fascicles indicate that there are fewer sarcomeres arranged in series which are thought to be more prone to being overstretched and damaged by forceful eccentric contractions, such as those conducted during the terminal swing phase of high-speed running (Timmins et al., 2016). Having more sarcomeres in series widens the fibre length, and longer fibre lengths allow for a more extensive muscular excursion. Fibre length influences skeletal muscle's length-tension and force-velocity curves (Lieber and Ward, 2011). Therefore, shorter fascicle lengths relative to biceps femoris long head length may increase the risk of a hamstring injury. However, this risk may be reduced by introducing sprint training and eccentric loading using the Nordic hamstring curl, which has been shown to increase fascicle length when implemented, decreasing the risk of hamstring injury (Bourne et al., 2017; McGrath et al., 2020; Mendiguchia et al., 2020).

2.4.5.2.4 Monitoring Workload

2.4.5.2.4.1 Internal Workload

Player monitoring measures stressors experienced by players during training sessions, matches, and other activities to improve athletic performance, assess player readiness and reduce injury risk (Kupperman and Hertel, 2020). The workload can be monitored and is generally quantified as internal and external. The psychophysiological response to external load is referred to as internal load (Benson et al., 2020). Session rating of perceived effort (sRPE) is a simple, non-invasive, practical, and widely recognised way of monitoring internal load (Comyns and Flanagan, 2013). sRPE in arbitrary units (AU) for each player is calculated by multiplying RPE (using the modified Borg CR-10) and session duration (min) (Malone et al., 2017).

No association was found between hamstring injuries and sRPE or session duration in either of the two studies that examined the relationship (Lolli et al.. 2020; Duhig et al., 2016). However, using sRPE has been associated with other injuries in various sports (Moreno-Perez et al., 2022; McCall et al., 2016; Delecroix et al., 2018; Myers et al., 2020; Colby et al., 2017). There are many advantages to using sRPE, such as no expense, no hardware required, and simple implementation, making it a good option for community sports such as Gaelic games. However, there are limitations, such as players can abuse the approach by giving a false sense of effort to impact later practice sessions (Bourdon et al., 2017). Therefore, when implementing a successful workload monitoring programme, it has been proposed that monitoring both internal (s-RPE) and external (GPS) workloads while taking the player and context into account is likely best practice (McCall et al., 2018). However, further research is needed as limited evidence currently supports this, particularly in the Gaelic games context where no previous research has investigated sRPE and hamstring injury risk.

2.4.5.2.4.2 External Workload

External load refers to the amount of physical work done and provides objective data on the amount and intensity of exercise (Benson et al., 2020). External load measurements include locomotive (e.g., distance travelled, number of accelerations) and mechanical (e.g., number of jumps, frequency of collisions) metrics, which may be recorded using wearable devices such as inertial measurement units and GPS (Benson et al., 2020; Ryan et al., 2020).

A simple way of measuring external load is using exposure time. One study in professional Spanish soccer found that the risk of hamstring injury was more significant when there was less match-play exposure (≤64 min) in the match preceding the injury (RR: 41%, $P < 0.0$) (Moreno-Pérez et al., 2023). Similarly, the risk of a hamstring injury increased with low cumulative exposure (≤95 min) for two consecutive matches (RR: 14%, $P = 0.01$). A practical choice to determine the possible risk of hamstring injury is cumulative playing volume in minutes, which is simple to measure and requires no external equipment (Moreno-Pérez et al., 2023), which may be helpful in the Gaelic games context. Coaches should thus use the record of player exposure times during games as a valuable tool to assess the risk of injury.

An integral part of sports performance is the capacity of high-speed running (Bangsbo et al., 2006; Malone et al., 2017). However, it is also a common mechanism for hamstring injuries (section 2.4.3.2). This has been proposed to be because, during the terminal swing phase of high-speed running, the hamstrings reach their maximum lengths, force, and activity when they act to slow down the flexing hip and fast-extending knee (Schache et al., 2012). Furthermore, it has been suggested that high-speed running's powerful eccentric contractions may accumulate eccentrically generated muscle damage, making the hamstrings more prone to strain injury (Ruddy et al., 2018; Timmins et al., 2016). Therefore it has been hypothesised that the external load metric high-speed running distance (distance above 24 km/hour) may be a risk factor for hamstring injuries.

Two studies have looked at the high-speed running distance and the risk of hamstring injury in Australian rules football, with both studies identifying a negative association between high-speed running distance and hamstring injuries, especially high-speed running distance above 24 km/hour (sprint speed) within a 7–14-day window (Ruddy et al., 2018; Duhig et al., 2016). The week before an injury or the acute workload (the distance covered in a week) had the largest effect of high-speed running distance on injury risk (OR=6.44) (Duhig et al., 2016). Similarly, there was a substantial increase in the risk of hamstring strain injury when the previous weekly distance covered above 24 km/hour was >653 m, the absolute week-to-week change in distance covered above 24 km/hour was >218 m, and a relative week-to-week change in distance travelled above 24 km/h greater than 2.00 (3.4-fold, 3.3-fold and 3.6-fold respectively) (Ruddy et al., 2018). The distance covered above 24 km/h as a percentage of the distance covered above 10km/h, greater than 2.5%, carried a risk ratio of 6.3 (Ruddy et al., 2018). Both these studies show that absolute high-speed running distances and rapid changes in high-speed running distances are risk factors for a hamstring injury. However, in contrast, a single study in professional Spanish soccer found that decreased high-speed running distance (<318.0m) in the match prior to injury and the cumulative distance of 2 matches (<667.4m) before the injury was a risk factor for hamstring injury (RR=1.53 and RR=1.17 respectively) (Moreno-Pérez et al., 2023). Although there is conflicting evidence, results suggest that there is a "sweet spot" with too little or too much exposure and sudden, sharp increases in high-speed running exposure increase the risk of a hamstring injury. Therefore high-speed running exposure and its association with hamstring injuries must be investigated in Gaelic games.

A study in AFL found that players who interchanged more frequently were at a decreased risk of injury, likely due to a reduced high-speed running exposure (Orchard et al., 2012). A shorter recovery time between matches increases the risk of hamstring strains in elite European soccer players (Bengtsson et al., 2013). Teams having less than or equal to 4 days recovery between each match had a hamstring injury rate of 5.74 injuries/ 1000 hours compared to teams having greater than or equal to 6 days recovery (injury rate of 4.47 injuries/1000 hours) (Bengtsson et al., 2013). Year-round training practices, a crowded calendar with cross-sport match schedules, and numerous Gaelic players playing with many teams concurrently (O'Keeffe et al., 2020) can lead to poor recovery between matches and training which may increase the risk of Gaelic games players sustaining a hamstring injury. Gaelic footballers have significantly greater levels of creatine kinase (a marker of fatigue) when compared to pre-match at 24 hours post-match (+159.9%, $p=.02$) and 48 hours post-match (+70.1%, $p<0.01$) (Daly et al., 2020) which is associated with increased inflammation and muscle damage and decreased muscle force production. Similarly, neuromuscular decrements exist in countermovement jump (-8.6%) and RSI (-15.6%) 24 hours post-match (Daly et al., 2020). Furthermore, less conditioned players have a greater compromised neuromuscular status post-match and were significantly lower than baseline for CMJ and drop jump at 48 hours post-match compared to better-conditioned players (Daly et al., 2022). This is critical for coaches to know as players can take greater than 48 hours to be fully recovered, and training sessions within this timeframe may increase the risk of injury due to lack of adequate time to recover. Similarly, it suggests that well-developed components of fitness may protect against the accumulation of fatigue (Johnston et al., 2015; Daly et al., 2022). Although not specific to hamstring injuries and high-speed running distance, Gaelic footballers who expose themselves to 10-15 weekly exposures of 95% of their max velocity over four weeks have a decreased risk (OR= .22, p =0.26) of subsequent injury (Malone et al., 2017). Gaelic footballers with a high chronic training load (OR=0.26) have a decreased risk of injury when they cover between 120-150 meters at max velocity compared to footballers with a low chronic training load (OR=3.12) that cover between 120-150 meters at max velocity. Similarly, among professional Australian football players, both over- and under-exposure to maximum speed (>85% of maximum velocity) efforts and volume (i.e., distance covered) is associated with a higher risk of non-contact lower limb injury (Stares et al., 2018). This indicates that there is a “sweet spot” and that both under and overexposure to high-speed running place the hamstring muscles at risk of injury. Therefore from a prevention perspective, exposing players to the correct amount of high-speed running and keeping the chronic load high may mitigate the risk of injury. Physically demanding and appropriate training builds physical attributes that guard against injury and prepare the player best for their sport (Gabbett, 2016; Malone et al., 2017). Therefore, monitoring workloads, particularly high-speed running distances, may help mitigate the risk of hamstring injuries.

A strong association exists between relative high-speed running exposure variables and risk of subsequent hamstring strain injury, particularly high-speed exposure in the 7 days prior to injury. A potential reason why players may be at a greater risk of hamstring injury may be due to the fatigue and eccentrically induced damage associated with high-speed running (Green et al., 2020). The results suggest that training load, particularly high-speed running distance, needs to be monitored, and excessive and sudden increases in high-speed running distance need to be avoided. However, it is essential to not just look at the risk factors in isolation (Meeuwisse et al., 2007), as several risk factors may be linked, such as high-speed running distance may affect eccentric strength, flexibility, fatigue etc. There is strong evidence for players to maintain a high chronic training load which should decrease rapid spikes in training, staying within the "sweet spot" or optimal workload (Gabbett, 2016), which helps reduce the risk of a hamstring injury. There appears to be no simple association between workload and risk of injury. Moreover, this association presumably depends entirely on the sport; therefore, extrapolating the results from one sport to another is not recommended. Consequently, research must be conducted within the Gaelic games context.

2.4.5.3 Other Hamstring risk factors investigated in Gaelic games

The most extensively researched modifiable risk variables for hamstring injury were flexibility and strength qualities (Green et al., 2020). Flexibility can be measured in many ways, including the active and passive knee extension tests, the max hip flexion active knee extension test, the sit and reach test and the straight leg raise test (de la Motte et al., 2019). No flexibility-related factor clearly is associated with the risk of hamstring injury in other sports according to the systematic reviews and meta-analysis (Green et al., 2020; Freckleton and Pizzari, 2013). One study has looked at the active knee extension test in male Gaelic games players and found no association with hamstring injury risk (O'Connor et al., 2019). This was similar to a meta-analysis which included 407 AFL players (RR=1.89, 95% CI 0.93 to 3.83, p=0.08) (Freckleton and Pizzari, 2013). However, there are conflicting results regarding ankle dorsiflexion range of motion and hamstring risk (Green et al., 2020; Freckleton and Pizzari 2013). A study on AFL players (Gabbe et al., 2006) and professional soccer players (van Dyk et al., 2018) found that reduced ankle dorsiflexion range of motion was a risk factor for a hamstring injury. Similarly, a single study on club Gaelic footballers found that players that had previously sustained a hamstring injury had significantly less ankle dorsiflexion range of motion than players with no previous injury (Lowther et al., 2012). Although the exact reason why reduced ankle dorsiflexion is associated with a hamstring injury is largely unknown, it is thought that running requires sufficient dorsiflexion mobility in the ankle (Bohannon et al., 1989). Reduced ankle range of motion during a sprint alters the foot's touchdown position, resulting in less horizontal force generation (Bezodis et al., 2015). Due to the strong association between hamstring muscle activity and greater horizontal force production (Morin et al., 2015), restricted ankle dorsiflexion mobility may result in more work for the hamstring muscle, exposing it to risk for injury. Although hamstring flexibility tests offer no insight for clinicians as a risk factor for a hamstring injury, further research on ankle dorsiflexion range of motion test may be beneficial in the Gaelic games context.

2.5 Injury Prevention Programmes Implementation

2.5.1 Introduction to Injury Prevention

Sports carry an inherent risk of injury, which is regarded as a significant public health concern (Cumps et al., 2008). Gaelic games are no exception, as identified in section 2.3.3, with a high incidence of injury and injury rates. A key goal of all stakeholders is to make sports safer for players, especially at the community level (Ross et al., 2021). Using an injury prevention model such as the TRIPP framework (Finch, 2006) for developing and implementing injury prevention exercise programmes is critical to reducing the occurrence of injuries, injury burden and the sequel to these injuries (Edouard and Ford, 2020; Mendonça et al., 2021). By lowering loading levels below pertinent injury tolerance limits or enhancing the body's ability to withstand and/or respond to loading patterns, interventions are intended to reduce the risk of injury (McIntosh, 2005). The main goal of injury prevention exercise programmes is to increase the body's tolerance through training. For injury prevention to be effective, it must be adopted and maintained (Finch, 2006). It is becoming evident that despite significant efforts from researchers and practitioners, injury rates in various sports situations are not improving (Tee et al., 2020). Therefore, a review of the approaches to injury prevention needs to be understood. Firstly, a brief review of the traditional simple and complicated approach to injury prevention must be understood, the common pitfalls to these approaches, and a review of a more detailed or complex approach (Tee et al., 2020; Bekker and Clark, 2016; Bittencourt et al., 2016). After this, it is essential to understand the injury prevention context within Gaelic games. This includes the development of injury prevention exercise programmes, the efficacy of these programmes, the awareness and use of these programmes and finally the different stakeholders' attitudes towards injury prevention.

2.5.2 Simple, complicated, and complex approach to injury prevention

Despite a large body of evidence supporting the benefits of injury prevention exercise programmes when they are adhered to, the effectiveness of sports injury prevention exercise programmes is inconsistent (Bekker and Clark, 2016), possibly due to the poor results when they are not adhered to. Transferring injury prevention exercise programmes from the research setting to the real-world setting, delivering programmes in real-world situations and maintaining programme fidelity is a difficult, long-term task

(Durlak and DuPre, 2008). Traditionally, two approaches have guided past work in this field of injury prevention, the simple approach and the complicated approach.

The first approach, or 'simple' approach, proposes that injury incidence can be decreased using a recipe-style approach such as the sequence of prevention (van Mechelen et al., 1992). Sports injuries are portrayed as simple occurrences for which an ideal intervention is sought, with interventions that either 'work' or 'don't work' (Bekker and Clark, 2016). However, the simple approach may not be able to tolerate variability in intervention effects, as this viewpoint focuses on discovering "what works" rather than attempting to manage such variances. The simple approach does little to help evaluate the vast amount of positive and negative findings in the field as research is solely conducted into the efficacy of interventions (Bekker and Clark, 2016). The simple approach is inherently flawed since there can never be a single, universally applicable yes-or-no response (Finch, 2006).

The second approach, or complicated approach, recognises the multidimensional complexity of interventions, with the goal of better understanding the impact of context, evidence-based content, and implementation effectiveness within the context that the intervention should work (Finch, 2006). To specify what to include or address in interventions targeted to maximise effectiveness, the complicated approach uses factors such as formulae, prior experience and historical precedent (Finch, 2006; Bekker and Clark, 2016). This approach is more “real world” than the simple approach, as it attempts to understand what influences intervention effectiveness, which is a welcomed approach (Bekker and Clark, 2016). However, the intervention is created under ideal circumstances before understanding the implementation environment or context, a major flaw in this complicated approach (Tee et al., 2020). Both the simple and complex approaches are reductionist and may explain why implementation to date has not been effective (Bekker and Clark, 2016; Bittencourt et al., 2016). The limitation of reductionist scientific methodologies is their inability to understand how dynamic interactions between diverse system-wide components may lead to implementing an injury prevention intervention in the real-world (Hulme et al., 2017).

Research consistently indicates that several other factors, including compliance, attitudes, and fidelity, influence intervention success which may be unaccounted for in the complicated approach (Bekker and Clark, 2016). In reality, the complicated approach translates into a prolonged process based on the assumption that we can reduce the gap if only the "missing" implementation aspects are better known (Bekker and Clark, 2016). Due to the complexity of the many stakeholder requirements and the dynamic nature of the sporting environment, knowledge translation and decision-making may not be as effective in affecting performance or injury (Bartlett and Drust, 2021). Bekker and Clark (2016) propose a complex approach that recognises that formulae, experience, and precedent have limited applicability across situations, times, and contexts, in contrast to the simple and complicated approaches. The complex approach has evolved as a method for investigating what appeared to be the limitations of traditional reductionist techniques, the simple and complicated approaches (Bekker, 2019). Interventions cannot be inherently effective under either of these approaches since outcomes are modified or influenced by interactions between intrapersonal, interpersonal, organisational, community, and societal factors, i.e. interventions cannot be evaluated as "good" or "wrong" but instead are viewed as "better" or "worse" depending on the context. The complex approach acknowledges that because interventions have several components that interact unpredictably and may be influenced by context, single factors are unlikely to account for considerable variations in effect size. Interventions should be studied in terms of 'what works for whom, when, where, and why,' considering not only whether they function but also how they interact, impact, and interaction within individuals and populations (Bekker and Clark, 2016). As entry points into the research process, it is critical to understand and consider both the context and demands of end-users (Bolling et al., 2018; Donaldson and Finch, 2012). The complex approach should not be considered a theory or method but rather a framework or lens (Castellani and Hafferty, 2009), emphasising the significance of understanding the impact of context in the sports injury research (Bekker and Clark, 2016). Strategies for preventing injuries must be developed using ongoing feedback loops that include lessons learned from previous intervention cycles. In the complex approach, the intervention should be portrayed as a stage in the intervention development process rather than as an end product. The problem is better understood with each loop of the intervention cycle, which also helps future preventative efforts (Tee et al., 2020). With this approach, injury prevention research focuses more on how effectively an intervention fits within a system, if it can be improved, and how. It becomes less about whether a particular intervention "works" or not.

2.5.3 The Importance of Context

In order to tackle issues in the practice of sports medicine, the context of the injury problem must be addressed. There is a need for a deeper understanding of the issue than what is currently known because of the complexity of sports injuries. The TRIPP model's first step, defining the 'injury problem', must consider the complexity and the context of sports injury before moving on to the next steps in the injury prevention framework (Figure 2.8) (Bolling et al., 2018). If one begins with no or limited information about the context of a sports injury, context-free preventative strategies will be developed (Bolling et al., 2018). To date, the implementation context has yet to be considered while developing most interventions (Figure 2.8) (Owoeye et al., 2018). Bolling et al. (2018) used an excellent analogy to help describe the context of using a F1 car. Testing the F1 car on an immaculate F1 track works perfectly. However, if the F1 car is used on a normal bumpy road, the car would be less than optimal. Therefore if we knew the context of where the car was to be used from the start, we would have designed a different car. However, instead of returning to the design table to produce a car that properly suits the context, we strive to change the road within the confines of our existing research paradigm to make our efforts valuable (Bolling et al., 2018).

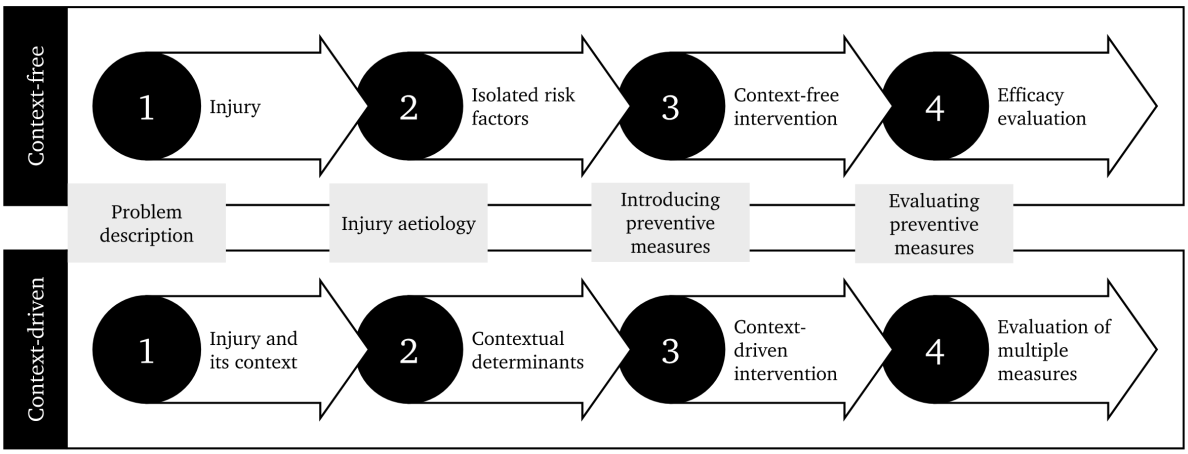

Figure 2. 8. Context-free versus a context-driven approach to the "sequence of prevention" (Bolling et al., 2018).

Historical, political, social, economic, scientific, cultural, organisational, and personal factors all interact to influence injury prevention strategies (Figure 2.9). When an injury occurs in a player, they have a variety of individual characteristics affecting them at a personal level, as well as several extra factors, such as socio-cultural and environmental/policy levels, which affect injury risk (Figure 2.9) (Bolling et al., 2018). A socio-ecological framework can be used to describe these interactions (Bolling et al., 2018). This framework takes into account the individual player (such as genotype, injury history, training history, occupation, and stress), the team (such as tactics, player interactions, coach interactions, and support networks), the standard of play, the sport itself, the governing body, and the society in which these factors exist and interact to produce injury outcomes, can be used to describe these interactions (Bolling et al., 2018). Similarly, it is crucial to recognise the resources available to the coach and player that they use, such as personnel, finances, equipment, time, and other resources needed to carry out the injury prevention interventions (Bishop, 2008). Although some settings are comparable, no two can be precisely the same; therefore, understanding that intervention contexts result from the combination of several components that impact one another in unforeseen ways is problematic for the generalizability of injury prevention strategies (Tee et al., 2020). Effective interventions are created and tested in a controlled environment before attempting to modify users' behaviour to accept our 'ideal' intervention. However, this is not the best method, and for injury prevention efforts to be effective, they should be built upon player behaviour (Verhagen, 2012).

The unidirectional nature of research is one of the main factors contributing to the research-practice gap (Bishop, 2008). "Practice-based evidence" is an alternative to conventional top-down research (Tee et al., 2020). Knowledge of the environment, culture, and infrastructure around sports injuries is necessary, as they may be so-called contextual variables of the injury prevention process (Bolling et al., 2018). Policymakers and practitioners need reliable and relevant information from research that considers real-world situations where people live, policies are developed, and interventions are applied (Rutter et al., 2017). It is recommended that the player is at the centre of all decisions, as demonstrated in Figure 2.9. To be effective, injury prevention efforts must be designed around the behaviours of players (Verhagen, 2012). The socio-ecological model can assist in understanding the dynamic interrelationships between levels and among other physical, biological, ecological, technical, economic, and social factors if the injured player is put in the centre of the viewpoint (Bolling et al., 2018). Instead of translating research into practice, we must consider context first to speak in a common language and get the best from injury prevention practices. It is critical that we ensure that injury prevention strategies are dynamic, effective in a variety of contexts, and flexible enough to change as those contexts do. Therefore, all stakeholders should be involved and engaged in designing more thorough injury prevention strategies while also realising how their respective responsibilities may affect injury and its prevention (Bolling et al., 2019).

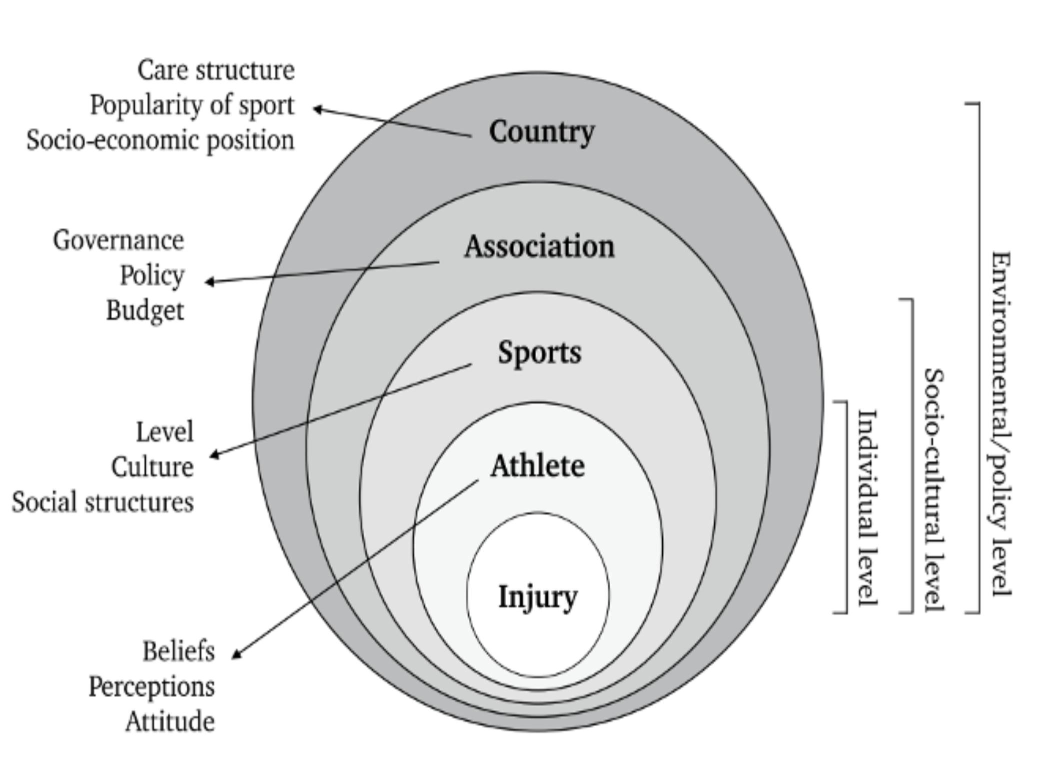

Figure 2. 9. A socio-ecological view of sports injuries that includes context at multiple levels, i.e. individual, socio-cultural and environmental (Bolling et al., 2018).

2.5.4 Gaelic games Injury Prevention

2.5.4.1 The development of Gaelic games Injury Prevention Programmes

As was highlighted in Section 2.3, injuries are a problem in Gaelic games, particularly hamstring injuries (related to stage 1 of the TRIPP framework for injury prevention). In Section 2.4, risk factors for common injuries were highlighted (related to stage 2). The following stages involve the development of a preventative measure and testing it under ideal conditions. Several injury prevention exercise programmes have been developed to reduce injuries in Gaelic games, including the GAA 15, the Activate GAA warm-up, The Athletic Development and Injury Prevention Program and the Camogie Injury Prevention Program, which has been adapted from the Activate warm up. The GAA 15 and the Activate GAA warm-up are neuromuscular injury prevention exercise programmes specific to Gaelic games that are carried out during the warmup (O'Connor et al., 2021; O'Connor et al., 2022; O'Malley et al., 2017; Schlingermann et al., 2018). The GAA Medical, Scientific, and Player Welfare Committee first developed the National GAA Injury Database in 2006, where participating inter-county teams registered injuries throughout the playing season, in line with TRIPP stages 1 and 2 (injury surveillance and aetiology). Following this, the GAA's Medical, Scientific and Welfare Committee conducted a systematic review to assess the effects of exercise-based interventions on injury incidence in team sports, which included the FIFA Medical Assessment and Research Centres - FIFA 11+ and the Santa Monica Orthopaedic and Sports (O'Malley et al., 2014). The developed injury prevention intervention is based on FIFA 11+PEP soccer programs implemented worldwide, findings from the National Injury Database since 2007, and a programme pilot (GAA.ie, 2021). Similarly, the Activate GAA warm-up was developed by Sports Institute Northern Ireland, Ulster GAA coaches and an expert group of sports medicine professionals who adapted the successful FIFA 11+ programme to meet the specific needs of Camogie/LGFA/GAA players to reduce ACL injuries in particular (Cumann Lúthchleas Gael Uladh, 2021). The Camogie Injury Prevention Program was officially adopted and rebranded from the Activate warm-up for the Camogie context (O'Connor et al., 2021). To address the problem of ACL and lower limb injury in Ladies Gaelic Football, the LGFA collaborated with the Sports Surgery Clinic in 2012 and developed The Athletic Development and Injury Prevention Program (Ladiesgaelic.ie).

2.5.4.2 Description of the Gaelic Games Injury Prevention Programmes.

The GAA 15 and Activate GAA warm-up are the two most popular Gaelic games-specific injury prevention exercise programmes, which take approximately 15 minutes to complete and include elements of strength, core stability, balance, plyometric and agility exercises, as well as movement control, specifically running, activation, jumping, and potentiation activities. By enhancing the neuromuscular capacities to produce quick and efficient muscle firing patterns, these training techniques aim to enhance movement patterns and skills (Hübscher et al., 2010). Both the GAA 15 and the Activate GAA warm-up are high-intensity warm-ups, but the Activate GAA warm-up emphasises integrating skills specific to the game (O'Connor et al., 2022). The interventions' primary goals are to increase neuromuscular control in bilateral and unilateral lower-limb activities, improve muscle strength and activation, and incorporate jump-landing techniques to reduce landing forces (O'Malley et al., 2017). Both programmes consist of 3 sections before training (Table 2.12). However, section 2 of the programmes' is only completed before training sessions and not matches (O’Connor et al., 2022). Both programmes are similar with subtle differences, but the Activate GAA warm-up has greater variation, as described in Table 2.12.

Table 2. 12. Structure and Exercises Included in the GAA 15 and the Activate GAA Warmup.

GAA15		**Activate GAA Warmup**		
Section 1: Running		***Phase 1: Running, Cutting and Landing Mechanics***		
Exercise	**Sets and reps**	**Exercise**		**Sets and reps**
20m slow runs forward	2 reps	*Out*	*In*	
Hip out 20m	2reps	Jog 20m	A skip 20m	2 reps
Hip in 20m	2 reps	½ pace run 20m	Ice hockey stop 20m	2 reps
Toe touches	4 reps x 2 sets	Jump, catch and land 20m	Pick-ups 20m	2 reps
Heel flick jog 20m	2 rep	Partner shuffle 20m	Lunge stop 20m	2 reps
Run 20m at 50% max speed	2 reps	Slow plant and cut 20m	Squat stop 20m	2 reps
Section2 : Improving the Mechanics & limiting risk of injury		***Phase 2: Strength, Plyometrics and Balance***		
Exercise	**Sets and reps**	**Exercise**		**Sets and reps**
Single leg deadlift	6 ES	*Circuit 1*	*Circuit 2*	
Single leg bridge	4 ES	Arabesque	Arabesque	5 ES
Reverse lunge	6 ES	Leg swings front	Leg swings lateral	10 ES
Nordic hamstring curl	Level 1; 3-5 reps Level 2; 7-10 reps Level 3; 12-15 reps	Partner push into lunge - straight	Partner push into lunge - multidirectional	5 ES
Front plank Level 1 - Start in front plank position, into side plank position without dropping hips to the floor, return to front plank, turn onto side plank, and return to front plank Level 2- Lift right leg in air, repeat on left, lift right arm, repeat on left. Level 3- In front plank position lift right arm and left leg together and repeat with opposite leg and arm	Hold for 6 sec in each position x 2 sets Hold for 5 sec in each position x 2 sets Hold for 3 sec in each position x 2 sets	Nordic hamstring curl	Nordic hamstring curl	5 to 10 reps
Side Plank Level 1 - Straight line from the uppermost shoulder to the uppermost foot.	30 sec x 2 sets	Front plank	Front plank with leg lift	30 sec (2 sec holds)

Level 2- Lift top leg up x 5sec. Level 3 - Make small circles with your top leg x 5 sec.				
Forward lunge	6 ES	Side plank with leg lift - knee bent	Side plank with leg lift - straight leg	10 ES
Jumps Level 1 - Counter movement jump Level 2 - Box jumps Level 3- Lateral jumps to single lad	8 reps x 2 sets	Split leg squats	Scissors jump	5 ES
Body weight squats Level 1 - double leg squats Level 2 - single leg squats	8 reps x 2 sets	Lateral hop and hold	Diagonal hop and hold	5 ES
		Prisoner squat	Prisoner squat	10 reps
		Countermovement jump	Countermovement jump with a twist	10 reps
Section 3: Sport Specific Movements		***Phase 3: Agility and Power***		
80% max speed run with slow jog back	20m x 2 sets	¾ pace run	High skips	20m x 2 sets
High plyometric bounding	6-8 reps x 2 sets	2 forwards 1 back	Bounds	2 sets
Plant and push while jogging	30 sec x 2 sets	Fast plant and cut with ball	One on one	20m x 2 sets
		Fast feet shuffle: front to back	Fast feet shuffle: right to left	10 ES
		Dynamic lunge		5 ES

Reps: Repetitions; ES: each side; Sec: seconds; m: meters; %: percentage.

2.5.4.3 The Efficacy of Gaelic Games Injury Prevention Exercise Programmes.

Once an injury prevention exercise programme is developed, it is critical to establish the efficacy of the prevention programme (stage 4 of the TRIPP framework) (Finch 2006). Although the GAA 15 (2006) and the Activate GAA warm-up (2014) were developed many years ago, there is minimal research on their effectiveness and benefits as injury prevention exercise programmes (Kelly and Lodge, 2018). Only two studies have examined the impact of the implementation of the GAA 15 on injury; one on male and female collegiate-level Gaelic footballers and hurling players (Schlingermann et al., 2018) and one on adolescent male hurlers (Kelly and Lodge, 2018) (Table 2.13). Incidence proportion was similar in collegiate Gaelic games players between the intervention group (12%) and control group (13%), but repeat incidence was half in the intervention group (14%) versus the control group (34%) (Schlingermann et al., 2018). In addition, injury rates were lower for the intervention group (13.57 and 2.62 injuries/1000 hours) than the control group (20.88 and 7.62 injuries/1000 hours) (Schlingermann et al., 2018; Kelly and Lodge, 2018). There was a 66% decrease in total injury rate in collegiate Gaelic games (Schlingermann et al., 2018), while training injuries were reduced by 45% and match injuries were reduced by 30% in the intervention group compared to the control in adolescent hurlers (Kelly and Lodge, 2018). Hamstring injuries, which are both prevalent and have a large injury burden in Gaelic games, had a 41% reduction in injury rates in the group that implemented the GAA 15 (Schlingermann et al., 2018). However, Schlingermann et al. (2018) reported a 16% reduction in the match injury rate in the control group compared to the group that implemented the GAA 15. A possible explanation for a decrease in injury in the control group could be that they included other injury prevention practices that were not controlled for. However, there were numerous limitations to this study, including a high rate of dropout among participants (42%), not specifying the number of males and females participants, not specifying differences in injury rates amongst males and females, and the intervention only lasted one collegiate season (Schlingermann et al., 2018). Similarly, the hurling study (Kelly and Lodge, 2018) was of short duration (September 2015 to April 2016) but did have a large number of participants. It was also implemented on adolescent hurlers, who have a lower injury rate compared to collegiate and adult Gaelic games players (Table 2.13), and the study relied on self-reporting of injuries which can lead to error (Coventry et al., 2023). The limited research in Gaelic games with regards to injury prevention is promising as both studies showed a decrease in injury rates, although they were subject to methodological limitations. Therefore, further longitudinal research is needed across all ages and levels of Gaelic games, with a focus on female Gaelic games players particularly required. There is no current published research on the Activate GAA warm-up investigating its efficacy in reducing injuries.

The GAA 15 was also shown to improve neuromuscular capacities which have the potential to decrease risk factors for injury alongside reducing injury rates. The GAA 15 significantly improved the jump-landing technique as measured by the Landing Error Scoring System (LESS) (adjusted mean difference 2.49 ($p = 0.001$)) (O'Malley et al., 2017) and dynamic postural control as measured by the Y-Balance performance (improved 1.8 % of normalised mean reach distance on the right ($p = 0.007$) and 2.3 % of normalised mean reach distance on the left ($p = 0.007$)) (Schlingermann et al., 2018). For dynamic balance, when compared to controls, the intervention group had a 3.85% ($p = 0.001$) increase in composite score on the right leg and a 4.34% ($p = 0.001$) increase on the left leg (O'Malley et al., 2017). Similarly, a significant increase in the Y-Balance composite score for the intervention compared with the control group for the right and left legs was noted in collegiate Gaelic games players. With regards to the jump-landing technique, the intervention group's mean LESS score improved from poor (LESS score > 6) to excellent (LESS score < 4), while the control groups mean LESS score stayed in the poor range (O'Malley et al., 2017). This current research shows that implementing the GAA 15 positively affects the dynamic balance and jump-landing technique, which may reduce the risk of injury (O'Malley et al., 2017; Schlingermann et al., 2018). However, the study by O'Malley et al. (2017) was of short duration (8 weeks), had a limited number of participants (78), 1 in every 4 did not return for post-intervention testing and was specific to males. Therefore, it is unknown if the GAA 15 would be as effective on females.

Only one study has looked at the effectiveness of the Activate GAA warm-up, which was in non-elite adult hurlers (n=117) (O'Connor et al., 2022). The intervention group significantly improved from pre to post-intervention in dynamic balance (3.0%) ($p<0.0001$, $\eta p2=0.23$), jump-landing technique (-29.7%) ($p<0.0001$, $\eta p2=0.34$), overhead squat (15.0%) ($p<0.0001$, $\eta p2=0.21$), single leg squat on the dominant limb (5.0%) ($p=0.04$, $\eta p2=0.0.04$), single leg squat on the non-dominant limb (15.8%) ($p<0.0001$, $\eta p2=0.12$) and they improved significantly greater than the control group ($p<0.05$).

However, there was no significant improvement in hamstring strength and eccentric adductor strength ($p>0.05$) (O'Connor et al., 2022). No increase in adductor strength was not surprising as the Activate does not include any specific adductor strengthening exercise. For hamstring strength in the dominant and non-dominant limbs, improvements of 7.3% and 8.2%, respectively, were reported and may be clinically significant (O'Connor et al., 2022). However, the authors recommended that an increase in Nordic hamstring exercise volume may be beneficial (O'Connor et al., 2022) as the Activate currently has between 5 and 10 reps per session (Table 2.12). In spite of this, a systematic review and meta-analysis concluded that when compared to a high-volume dosage, a reduced Nordic hamstring exercise volume prescription had no negative effects on adaptions in eccentric strength (Cuthbert et al., 2020). However, hurlers in the Activate study only performed an average of 8 to 16 reps per week (O'Connor et al., 2022), which is less than the minimum amount (21 reps) in the systematic review and meta-analysis. The Activate GAA warm-up improved a variety of injury risk variables, including landing mechanics, postural control, and movement quality. Based on the latest research, a coach-led injury prevention exercise program that is delivered as part of a warm-up can effectively reduce players' risk of injury in Gaelic games (O'Connor et al., 2022; Schlingermann et al., 2018; O'Malley et al., 2017; Kelly and Lodge, 2018). However, for these programmes to be successful in the real world, they must be accepted and implemented as planned (Finch and Donaldson, 2010).

Table 2. 13. Effectiveness of the GAA 15 at Reducing Injury Rates.

Year & Author	**Definition of injury**	**Duration/ Methods**	**Participants**	**Main findings**	
				Intervention Group	*Control Group*
Kelly and Lodge, 2018	Any injury sustained during hurling training or competition resulting in time lost from play or player reported restricted performance	1 season. Intervention: GAA 15 Control: own warm up	516 male secondary school hurlers (mean 15.9 years)	Training IR 8.78/1000 hrs Match IR 25.62/1000 hrs	Training IR 15.83/1000 hrs Match IR 36.32/1000 hrs
Schlingermann et al., 2018	Any injury that prevents a player from taking a full part in all training and match play activities typically planned for that day, where the injury has been there for a period greater than 24 hours from midnight at the end of the day that the injury was sustained	1 season. Intervention: GAA 15 Control: own warm up	131 male and female collegiate Gaelic games players (18–40 years)	Training IR 1.24/1000 hrs Match IR 14.41/1000 hrs Hamstrings IR 0.62/1000 hrs	Training IR 6.39/1000 hrs Match IR 12.42/1000 hrs Hamstrings IR 1.05/1000 hrs

IR: injury rate; hrs: hours.

2.5.4.4 Gaelic games Injury Prevention Programmes Implementation.

Current research suggests that implementing the GAA 15 can reduce injury rates (Section 2.5.4.3). The GAA 15 and the Activate GAA warm-up have also been demonstrated to increase neuromuscular capacities, which may decrease the risk of injury. Although these programmes are effective in controlled environments, adoption and implementation in the real world, particularly community sports, can be challenging (Donaldson et al., 2018). Only two studies in total have looked at injury prevention exercise programme implementation in Gaelic games, one in Camogie coaches and players (O'Connor et al., 2020) and one in Gaelic football coaches (Reilly and Kipps, 2017). Only one study has looked at the awareness of injury prevention exercise programmes in Camogie players and coaches and found that awareness was low in both players (13.9%) and coaches (32.0%) (O'Connor et al., 2020). The likelihood of using injury prevention exercise programmes is low without widespread awareness of the programmes. The use of injury prevention exercise programmes is also low, with 34% of Camogie coaches surveyed reporting using an injury prevention exercise programme with their team. In comparison, only 11.8% of players indicate using an injury prevention exercise programme with their team (O'Connor et al., 2020). However, this study examined Camogie only and may not represent the whole Gaelic games context. Similarly, a study on the use of injury prevention exercise programmes by club Gaelic football coaches in both Mayo and London reported that only 7.7% of coaches surveyed implement the GAA 15 injury prevention exercise programme (Reilly and Kipps, 2017). However, this study had very limited numbers (n=26) and only looked at coaches, just one of the many stakeholders. Poor programme uptake and implementation will ultimately result in poor programme outcomes (Donaldson et al., 2017). Therefore establishing the attitudes of stakeholders towards injury prevention and the barriers and facilitators that influence the successful uptake of injury prevention exercise programmes stakeholders within their context is essential, if the programme is to be successful (Bolling et al., 2018; Bekker and Clark 2016; Martins de Oliveira et al., 2022; O'Brien and Finch, 2016; Finch and Donaldson, 2010).

2.5.5 Stakeholders Perspective

For the initial adoption, implementation and long-term maintenance of injury prevention exercise programmes to be truly successful, sports injury prevention researchers must understand what influences and drives the safety action of coaches, players and administrators in the context of their daily lives (Donaldson and Finch, 2012). The implementation dimension refers to a measure of the extent to which the intended target groups use the intervention (Table 2.15). The only way to guarantee this is to take an active role and include them in all stages of intervention development, from needs assessment through implementation planning and evaluation. Each level will have a unique experience, areas of expertise, and perspectives on the issue (Edouard and Ford, 2020). Data that may be considered compelling for researchers might not be regarded as compelling for those in the sport who have the power to implement an intervention or policy that increases uptake (Hanson et al., 2014). It should come as no surprise to researchers that overlook the contextual, implementation, and process drivers of intervention success when stakeholders are reluctant or unable to apply evidence-based sports injury interventions (Hanson et al., 2012; Donaldson and Finch, 2012). Stakeholders such as players, coaches and club officials can offer vital insight into the best fit and what is realistic, economical, and long-term in their community (Hanson et al., 2014). For injury prevention strategies to be translated into practices, they must first be designed by clinicians, researchers and members of the target community together, where each group's contribution is valued. Each partner brings a unique skill set to the table that is essential for effectively implementing evidence-based practice. To guarantee that comprehensive, evidence-based interventions are also practical and relevant to the actual world of sports medicine, all stakeholders' knowledge must be brought together (Hanson et al., 2014). Successful intervention implementation requires more than an effective programme (Donaldson et al., 2018), and a bottom-up approach should be used for more successful translation from research into practice (Finch, 2011). It's not enough to know what should be done; you also need to understand what can and how it should be done. This can be achieved by understanding the context of injury prevention and the barriers and facilitators of injury prevention (Figure 2.10).

Figure 2. 10. Integrating expertise to ensure comprehensive, evidence-based interventions that are practical and relevant when applied in the real world (Hanson et al., 2014).

2.5.5.1 Attitudes to Injury Prevention

The use of injury prevention programs has been argued to be influenced by factors such as stakeholder attitudes toward injury prevention (Finch, 2006; Rees et al., 2021). Players, coaches, and clinicians/medical professionals agreed that the risk of a sports injury is inevitable in elite sports participation since players always strive to enhance their performance by pushing their boundaries (Bolling et al., 2020). The stakeholders all agree that injury prevention is essential and is a part of their sports routine (Bolling et al., 2020). However, attitudes are sometimes different across all stakeholders. A study on Camogie revealed that 76.1% of coaches believed that activities included in injury prevention exercise programmes are relevant and beneficial to players compared with 90.6% of players, and more players (69.5%) agreed and/or strongly agreed that injuries were an issue with their team than coaches (40.2%) (O'Connor et al., 2020). Not including all stakeholders in developing injury prevention exercise programmes may increase the risk of poor adoption and implementation in this group. Although awareness and use of Gaelic games-specific interventions were poor, the vast majority of Gaelic football coaches believe injury prevention can reduce injuries (96%), and Camogie players (95%) and coaches (96%) believe that injury prevention is an essential component of training (Reilly and Kipps, 2017; O’Connor et al., 2020). Camogie coaches (95.7%) agree that it is important to have up-to-date knowledge of injury prevention strategies. This is crucial because this positive attitude about a behaviour could greatly impact how well a programme is adopted and followed (Soligard et al., 2010). Thus, a coach with a positive attitude to injury prevention is more likely to deliver an injury prevention strategy, which is critical to improving compliance and, ultimately the success of the programme. Similarly, it is essential to identify those with a poor attitude to injury prevention and educate them on the benefits of using an intervention. However, there is currently a paucity of this information with regard to coaches' and players’ attitudes towards injury prevention in the Gaelic games context.

2.5.5.2 Barriers to successful injury prevention programme implementation

Despite having a generally favourable attitude about injuries and injury prevention interventions, barriers can prevent a stakeholder from implementing preventative measures. It is critical that we understand these barriers within the context of the sport. Camogie coaches (41.9%) agree that they haven’t received training to implement an injury prevention exercise programme or do not have access to anyone with the appropriate skills or knowledge to assist them with implementing an injury prevention exercise programme (O’Connor et al., 2020). Similarly, Gaelic football coaches believe they do not receive enough resources and assistance to help with delivering injury prevention exercise programmes (Reilly and Kipps, 2017), similar to camogie coaches who feel they lack the knowledge, expertise, and abilities necessary to execute an injury prevention exercise programme with their team, as well as the belief that there is a lack of educational resources to help them (O’Connor et al., 2020). One qualitative study investigated the barriers and facilitators to injury prevention in Ladies Gaelic Football (Corrigan et al., 2023). This found similar in that lack of awareness, resources and confidence in delivering a programme were common barriers. However, other barriers such as programme repetition, non-sport specific, lack of time and lack of health and fitness personnel to help deliver injury prevention exercise programmes were also perceived as barriers in Ladies Gaelic Football (Corrigan et al., 2023).

However, the Camogie injury prevention program has now been introduced as a part of coach education programmes. All coaches will receive the training in the future and eventually reach all Camogie coaches nationally (O'Connor et al., 2020). This mandatory injury prevention training in Camogie will be vital as it should improve coach knowledge and awareness, which may reduce injury rates in Camogie in the future. Nonetheless, Camogie is just one of the Gaelic games codes, and injury prevention workshops are not mandatory in other codes. As well as that, no research has looked at the attitudes, barriers, and facilitators to injury prevention in Gaelic football and hurling.

Further research is needed to investigate the attitudes of coaches and players and their perceived barriers and facilitators to using injury prevention in different contexts of Gaelic games, such as across codes and levels. This is vital so that future injury prevention strategies are developed using the socio-ecological model suggested as a tool for understanding what influences injury prevention implementation across various levels (Bolling et al., 2018; Bruder et al., 2021). The bottom-up approach is crucial for contributing to developing injury prevention exercise programme strategies as it ensures that all significant stakeholders are involved from the outset (O'Connor et al., 2021). Intervention efforts may become more successful by aiming to remove the barriers and assist the facilitators that impact these stakeholders.

Getting input from all stakeholders on various levels of the socio-ecological model is critical. One method of doing this is clearly stated in the FootyFirst injury prevention exercise programme. Once the context of the end users is understood, the next step used in the AFL FootyFirst injury prevention exercise programme was including and integrating league and club/administration and some renowned community and elite-level coaches in the development and execution of FootyFirst strategies (Donaldson et al., 2017). Using Intervention Mapping (a method that facilitates effective health promotion planning and evaluation) Step 5, Donaldson et al. (2017) reported seven tasks that were applied when planning the implementation of the FootyFirst injury prevention exercise programme, which could be used or adapted to future developments of Gaelic games injury prevention strategies (Table 2.14). Intervention mapping step 5 mainly focuses on planning programme adoption, implementation and maintenance. This strategy was designed to bridge the gap between research-driven (top-down) and community-driven (bottom-up) programme implementation processes. This was done in conjunction with a solid researcher-practitioner partnership and a structured method of engaging with programme end users, which ensured that the strategy would be feasible and maintained within the context of the sport (Donaldson et al., 2017). This highlights the importance of the inclusion of each level of the socio-ecological (Figure 2.9) model when designing a successful implementation strategy.

Table 2. 14. How the Intervention Mapping Step 5 Tasks Were Applied When Planning the Implementation of FootyFirst (Donaldson et al., 2017).

Intervention Mapping Step 5 Task	**Purpose**	**Application and key questions in the interventions implementation planning project**
Task 1 - Identify potential intervention adopters and implementers.	To identify individuals and organisations that would be involved in, or would influence, the interventions adoption and implementation by community coaches within the targeted league.	"Who will decide to use the intervention and who will actually deliver the intervention to the players?"
Task 2 - Establish an implementation planning group with representatives of potential intervention adopters and implementers.	To link the interventions developers (i.e., the project team) to programme adopters/implementers (i.e., coaches).	A league-specific intervention Implementation Advisory Group was established including representatives of the project team and community coaches, and 'change agents' (e.g., league/club administrators) who could influence the interventions adoption and implementation decisions and behaviours.
Task 3 - State interventions use outcomes and specify reach, adoption and implementation performance objectives	To describe what the implementation activities should accomplish including who had to do what for coaches to be reached and the intervention to be adopted and implemented.	"What do community coaches need to do to constitute the interventions, adoption and implementation of coaches?"
Task 4 - Specify determinants of the interventions reach, adoption and implementation.	To identify what will influence whether or not coaches performed the actions needed to accomplish the performance objectives.	"What is likely to influence whether coaches adopt and implement the intervention?"
Task 5 - Identify change objectives for the interventions reach, adoption and implementation.	To link the interventions reach, adoption and implementation performance objectives and determinants, to create change objectives.	"What is it about the determinants (from Task 4) that need to change for coaches to achieve the performance objectives (from Task 3)?"

Task 6 - Select theory-informed, evidence-based and context-specific intervention reach, adoption and implementation strategies.	To identify specific strategies to achieve the change objectives.	"What could be done to help, support or encourage coaches to achieve the agreed change objectives?" "Why is a particular implementation strategy likely to work?"
Task 7 - Design interventions for the interventions reach, adoption and implementation.	To develop and produce materials and resources to operationalise the implementation strategies.	Generated a set of evidence-base, theory-informed, context-relevant activities and resources that reflected the thinking and planning done in Task 1–6 that, when undertaken, should lead to improve the interventions reach, adoption and implementation by community coaches.

2.5.6 The Reach Efficacy Adoption Implementation Maintenance Sports Setting Matrix

Research shows that when interventions are applied to the real-world sporting situation from a lab setting where they were developed, they can be ineffective because the target group does not use the intervention in the way that they were intended (Finch and Donaldson, 2010). As previously described, future gains in sports injury prevention will only be achieved if research efforts are oriented towards understanding the implementation environment for injury prevention and continuing to establish the evidence-base for the usefulness and effectiveness of interventions (Finch, 2006). The TRIPP model's stages 5 and 6 are particularly significant for injury prevention since establishing targets for specific implementation initiatives requires an awareness of the barriers and facilitators to general acceptance and sustainability of prevention measures. Consultations with sports organisations have indicated that clear guidelines are needed to advance safety by translating scientific data into practical tools and approaches that can be implemented on a local level. The Reach Efficacy Adoption Implementation Maintenance Sports Setting Matrix (RE-AIM SSM) framework (Table 2.15) was developed to improve the translatability and impact of sports injury interventions across the sports delivery hierarchy (Finch and Donaldson, 2010). As well as being a planning framework, the RE-AIM SSM can be used to thoroughly evaluate the impact of intervention at each dimension (Gaglio et al., 2013). Each dimension should be assessed at different levels (Table 2.16), such as national, regional, state/provincial, club, team and individual, for different translatability and impact described in Table 2.15.

Table 2. 15. Description of Each Dimension of the RE-AIM SSM Framework (Finch and Donaldson, 2010).

Key dimensions	**Description**
Reach	The proportion of the target population that participated in the intervention.
Efficacy	The success rate if implemented as intended, defined as positive outcomes minus negative outcomes.
Adoption	The proportion of people, settings, practices and plans that adopt the intervention.
Implementation	The extent to which the intervention is implemented as intended in the real world.
Maintenance	The extent to which the intervention is sustained over time.

Table 2. 16. Characteristics At Each Level That Should be Evaluated At Each Dimension of the RE-AIM SSM Framework (Finch and Donaldson, 2010).

Level	**Dimension that should be evaluated at different levels**
National, Regional, State/Provincial	Commitment Communication strategies Education and training provided Finance and other resources allocated Formalising of safety committee structures and monitoring processes policies Documented decision processes Attitudes/knowledge of key personnel
Club	Organisational infrastructure Policy development/implementation/ monitoring Training/support for coaches Sports administrative support/monitoring promotion and communication Attitudes/knowledge of club officials and key administrators
Teams	Implementation of training guidelines Coach plans/practices Attitudes/knowledge Documentation Accountability to club Communication strategies
Individual	The proportion of participants exposed to the intervention Participant awareness/knowledge of interventions Proportion of participants incorporating the intervention into routine activity Rates of relevant injuries

There have been two systematic reviews that have examined whether injury prevention interventions in ball sports (studies, n=52) (O'Brien and Finch, 2014), and rugby (studies, n=74) (Barden et al., 2021) have evaluated their '*reach*', '*effectiveness*', '*adoption*', '*implementation*' and '*maintenance*' as per the RE-AIM SSM. They found that most research focuses on the 'efficacy' of interventions, with little attention paid to the 'adoption, implementation, and maintenance' of prevention efforts where there are significant information gaps (Table 2.17). This is despite the fact that effective implementation and maintenance of any injury-prevention programme are critical to achieving the desired results (Finch, 2006). To achieve this further research is needed to investigate coaches' and players' current awareness of, use of and their attitudes towards the current injury prevention exercise programmes. In Gaelic games, one study evaluated an injury prevention exercise programme developed specifically for Camogie using the RE-AIM SSM and was published after the systematic review (Table 2.17) (O'Connor et al., 2021). In Camogie, reach is very poor, with only 21.9% of Camogie coaches aware of any injury prevention exercise programme (O'Connor and Lacey, 2020). As was detailed in Section 2.5.4.3, Gaelic games specific injury prevention exercise programmes are effective at reducing injuries and injury risk factors (O'Connor et al., 2022; Schlingermann et al., 2018; Kelly and Lodge, 2018; O'Malley et al., 2017). However, the adoption of injury prevention exercise programmes is also limited in Gaelic football and Camogie coaches (O'Connor and Lacey, 2020; Reilly and Kripps, 2017) and has not yet been examined in hurling and Ladies Gaelic football. Four weeks after an injury prevention exercise programme workshop, 72.5% of coaches implemented the Camogie injury prevention program, and 95% believed it could be maintained over multiple seasons (O'Connor and Lacey, 2020). Therefore, there is potential for improved adoption, implementation and possibly maintenance in Gaelic games, as demonstrated by this study by educating coaches and making them aware of injury prevention exercise programmes which may positively affect injury rates in the future. However, there is a paucity of research in the Gaelic games context, particularly on the reach and adoption of injury prevention exercise programmes. Further research is needed in this area to improve adoption and maintenance by understanding the attitudes of key stakeholders that will be utilising and implementing injury prevention exercise programmes.

Table 2. 17. Evaluating the Use of Each Dimension of the RE-AIM SSM Framework in Sport (Barden et al., 2021; O'Brien and Finch, 2014; O'Connor et al., 2021).

Dimension	**Author & Year**		
	Barden et al., 2021	O'Brien and Finch, 2014	O'Connor et al., 2021
Reach	26.2%	34%	Coaches across Ireland in 7 county boards
Effectiveness	49.6%	58%	99.0% felt that a workshop increased their motivation to implement the CIPP 88.5% confident delivering the intervention post workshop
Adoption	SL: 32.8% DAL: 6%	SL: 1% DAL: 7%	Adopted into formal coaching course Development of online resources
Implementation	15.6%	36%	72.5% implemented 4 weeks post workshop
Maintenance	IL: 10% SL: 19%	IL: 1% SL: 0%	95% of coaches believed that the program could be maintained over multiple seasons

DAL: delivery agent level; IL: individual level; SL: setting level; CIPP: Camogie Injury Prevention Program; %: percentage.

2.5.7 Summary

Injury prevention warm-up programmes have been developed for Gaelic games, and they are effective in controlled environments. However, their effectiveness in the real world needs to be improved due to their relatively low awareness and uptake. Therefore further research must be conducted to examine further the awareness of and use of these programmes across many stakeholders in Gaelic games. It is also crucial that their attitudes towards injury and injury prevention and the barriers and facilitators to injury prevention are understood so that strategies fit within the context of Gaelic games. Before we see any real change in reducing injury rates and burden, we must understand the context for injury prevention implementation in the Gaelic games community across both genders and level of play. Attention must now be turned to closing the gap between research-driven (top-down) and community-driven (bottom-up) programme implementation (Donaldson et al., 2017). If players, coaches and club administrators are involved in the implementation planning, the recommended implementation methodologies will likely be more feasible and maintainable beyond the life of research. Understanding the context of the end users is the priority in getting coaches and players to adopt and implement the Gaelic games programmes. Further research is needed to understand what is the best way to increase the uptake of injury prevention exercise programmes because only the prevention programme that is adopted and implemented will be effective in reducing injuries (Finch, 2006). This can be achieved by researching all codes of Gaelic games, investigating awareness and use of injury prevention exercise programmes, attitudes towards them and possible barriers and facilitators to their use. It should be noted that injury prevention can take a more individualised approach, such as reducing injury occurrence independently for every player by first determining what training stimuli a specific person appears to need based on various "screening" evaluations (Lahti et al., 2020). This approach recognizes that players have varying levels of fitness strength flexibility and injury history, which can influence their susceptibility to hamstring injuries. Individualisation of injury prevention may improve compliance issues faced with universal injury prevention exercise programmes as players may see it as more impactful and increase their buy-in (Lahti et al., 2020). Although there are numerous benefits to this approach, there needs to be more research on its use. Similarly, a multifactorial individualized approach requires a lot of resources and finance that is not readily available to Gaelic games teams, particularly at the non-elite level. Therefore it is critical to understand the awareness and use of injury prevention exercise programmes, attitudes towards them and possible barriers and facilitators to their use.

2.6 Conclusion of Literature Review

Gaelic games are demanding sports with a particularly large high-speed running exposure (Young et al., 2021; McGahan et al., 2021; Young et al., 2018; Malone et al., 2022). Injury rates are high across all codes of Gaelic games (O'Connor et al., 2021; Buckley and Blake, 2018; Murphy et al., 2012; Murphy et al., 2010). Hamstring injuries are particularly high and, from the limited research, also have a significant burden of injury (O'Connor et al., 2021; Roe et al., 2016). Therefore injury prevention efforts should be focused on these injuries. Non-modifiable risk factors for hamstring injuries, such as increasing age and previous injury, have been well established. Modifiable risk factors such as eccentric hamstring strength and high-speed running exposure have yet to be monitored continuously in Gaelic games. Efficacious injury prevention exercise programmes have been established (O'Connor et al., 2022; Schlingermann et al., 2018; O'Malley et al., 2017). However, there is a paucity of research investigating if they are well implemented in all codes of Gaelic games. Furthermore, there is limited research on the attitudes of coaches and players towards injury prevention (O'Connor et al., 2020), which is a crucial factor for intervention compliance. As a result, this research will delve into these gaps in the literature to present a comprehensive picture of the epidemiology and risk factors for hamstring injuries. It will also aim to gain a greater understanding of the injury prevention implementation context within Gaelic games.

Chapter 3 Study 1 - Injuries in Irish Male and Female Collegiate Athletes

Teahan, C., O'Connor, S. and Whyte, E., 2021. Injuries in Irish male and female collegiate athletes. *Physical Therapy in Sport*, 51, pp.1-7.

3.1 Introduction

There are many health-related benefits associated with sports participation, including reducing the risk of chronic diseases such as cardiovascular disease (Warburton et al., 2006). However, participation also comes with the risk of musculoskeletal injury, a major contributor to sports participation dropout. Dropout rates in Ireland peak at the university-age level, with one in four reporting that injury led to dropout (Lunn et al., 2013). Therefore, developing and implementing effective injury prevention exercise programmes are critically important in this age group.

The first stage of this is to establish the extent of injury in this population (van Mechelen et al., 1992; Finch, 2006). Gaelic Football, hurling/Camogie, soccer, and Rugby are four field-based team sports with high participation by both males and females at this age level. These popular sports consist of high-intensity running, sprinting, jumping, turning, kicking, strength, endurance, flexibility and tackling, although tackling permitted in each sport varies considerably with physicality intensifying from soccer, Gaelic games to Rugby (McIntyre, 2005; Roberts et al., 2008; Strudwicket al., 2002). Soccer permits you to tackle with your feet, but you must get the ball; Gaelic games allow more contact than soccer and permits you to use your hands and shoulder charges are permitted within reason, and Rugby allows the most contact allowing with a tackle being defined as “when a ball carrier (a player carrying the ball) is held by one or more opponents and is brought to ground” (World.Rugby).

Previous research in collegiate Rugby has demonstrated a discrepancy in injury rates (male: 22.5/1000 athlete exposures, 37.7/10000 athlete exposures; female: 22.7/1000 athlete exposures, 28.1/10000 athlete exposures) compared to elite Rugby (81 injuries and 91 injuries/1000 h) and amateur rugby (46.8/1000 h) (Kerr et al., 2008; Peck et al., 2013; Williams et al., 2013; Brooks 2005; Yeomans et al., 2018). However, recent research examining collegiate Rugby rates is lacking, and no previous research has examined injury incidence in Irish collegiate Rugby. Collegiate soccer has a low injury rate (male: 8.07; female: 8.44/1000 athlete exposures) when compared with Rugby (Roos et al., 2016). Match injury rates have decreased from 18.75 to 15.65 injuries/1000 athlete exposures in males and 16.44 to 13.13 injuries/1000 athlete exposures in females in National Collegiate Athletic Association (NCAA) (Agel et al., 2007; Dick et al., 2007; Di Stefano et al., 2018; Kerr et al., 2018). This may be due to the effectiveness of the FIFA 11+, a soccer-specific injury prevention exercise programme in recent years. Previously it has been reported that the FIFA 11+ could reduce injuries by 46.1% in male NCAA college players (Silvers-Granelli et al., 2015). However, like Rugby, no research has examined collegiate college player injuries in Ireland. A single study has examined injuries in collegiate male (O'Connor et al., 2016) and female (O'Connor et al., 2021) Gaelic footballers. Females displayed a higher injury rate (17.9 vs 12.6 injuries/1000 h). No previous research has examined injuries in collegiate hurling/Camogie players. At the elite level, high injury incidence is reported in hurling (61.8 and 102.5 injuries/1000 h) and Camogie (26.4 injuries/1000 h) (Murphy et al., 2010; Blake et al., 2014; Buckley and Blake, 2018). However, in most sports, injury rates differ at the collegiate level, which may be due to the fact that elite players may be older; therefore, they may have an increased history of previous injury, which are two strong risk factors for injury (Arnason et al., 2004).

Of all the epidemiological studies on collegiate players, only Gaelic football reports the burden of injury (O'Connor et al., 2016; O'Connor et al., 2021). It has been argued that epidemiology needs to move on from reporting injury rates and severity in isolation (Bahr et al., 2017). Burden is a cross-product of incidence and severity (expressed as days absent per 1000 player hours), which will give the clinician a better understanding of the injury's consequences for the team/management (Hägglund et al., 2013). The lower the injury burden, the better for the player/team. Given the importance of injury prevention in this population, a better understanding of injury and burden is needed in these sports to try and reduce the risk of sports dropout in this vulnerable population. The aim of this study was to capture both the injury incidence and injury burden in Irish male and female collegiate players in the four most popular collegiate field sports - Gaelic football, hurling/Camogie, soccer and Rugby.

3.2 Methods

This was a prospective cohort study of male and female collegiate field-based players during one academic season (September-March depending on the success of the team). Ethical approval was granted by Dublin City University's Ethics Committee (DCUREC/2019/206).

3.2.1 Participants

The participants were recruited from one Irish collegiate institution by convenience sample. The primary investigator contacted the head of each sports organisation within the university, who introduced the primary investigator to all the different management teams for the various sports. The primary investigator held an information evening to explain to management and players the aims of the study and all players received a plain language statement. Before the start of the study, written, signed informed consent was given. Following this, a student athletic therapist was assigned to every team that was included in the study. Six hundred and seventy-two college players (n=416 male and n=256 female) playing either Gaelic football, hurling, Camogie, soccer, and Rugby were recruited.

3.2.2 Procedures

An injury was defined as any physical condition that prevents a college player from full participation for a period greater than 24 h (Brooks, 2005). The condition was not classified as an injury if the college player was available for participation within 24 h. The primary investigator, a Certified Athletic Therapist, was onsite at all home-based training and matches. All training and matches were attended by third and fourth-year student athletic therapists with at least one year of clinical experience and passed all classes on injury diagnosis and first aid. Student athletic therapists assessed any injury that occurred at home and away matches and training which was overseen by a Certified Athletic Therapist. Following the preliminary assessment, the injured college player was referred to a student-led clinic held on campus for treatment and confirmation of diagnosis, which was supervised by Certified Athletic Therapists. Once the diagnosis was confirmed, a standardised injury report form was filled out, which has previously been utilised in previous research (O'Connor et al., 2016) detailing injury information such as injury onset, recurrence, contact injury, mechanism, location, structure injured, type of injury, and date of injury. The injury report form was filled out by the student athletic therapists and reviewed by the Certified Athletic Therapist. The date was noted on the injury report form when the college player resumed full participation, ensuring that injury severity could be calculated. Full participation was defined as the moment a college player was fully available for match selection and/or full training (van der Horst et al., 2017). Injury severity was defined by the number of days that the college player was unavailable for training and competition, from the date of onset until the college player is fully available for training or competition (Bahr et al., 2020). Severity was classified as minor (<7 days), moderate (8-28 days) and severe (>28 days) (Bahr et al., 2020). Recurrent injuries were defined as an injury that occurs in the exact location and same tissue as a previous injury after the college player returns to play, organised into early recurrence (< 2 months), late recurrence (2-12 months) and greater than 12 months (>12 months) (Fuller et al., 2006). The primary investigator checked, collected, and updated the forms weekly. In the event that a clinician diagnosed a player outside of the college, the primary investigator contacted the injured player and confirmed the injury.

3.2.3 Statistical analysis

Data was transferred and stored on Excel (2020, version 16.34; Microsoft Corporation, Redmond, WA, USA) and checked for missing information. The data was then transferred and analysed using SPSS (2017, version 25.0; IBM Corp, Armonk, NY). Incidence proportion (IP) was calculated by the number of injured college players during a season divided by the number of college players at risk during the season (van Mechelen et al., 1992). The repeat incidence proportion was calculated by the number of college players who sustained more than one injury during the season divided by the number of injured college players during the season (Fuller et al., 2006). Injury rates were calculated by the number of injuries divided by the total player exposure hours multiplied by 1000 and were expressed as injuries per 1000 hours. The student athletic therapist assigned to the team recorded exposure hours and participation numbers, and the exposure time was only counted when there was collective training or a match and the individual was actively participating. Injury burden was calculated as the total days lost divided by the total exposure hours multiplied by 1000 and is expressed as days absent per 1000 player hours. Confidence intervals for rates were calculated using Poisson Distribution. Descriptive statistics were used for all other variables, and 95% Confidence intervals were calculated for all proportions using OpenEpi (Wilsons score) (https://www.openepi.com/Proportion/Proportion.htm).

3.3 Results

There were 179 injuries reported in 672 college players. Incidence proportion revealed that 0.266 of college players sustained an injury throughout the academic season (Table 3.1). Of the college players that sustained an injury, 0.086 sustained at least one repeat incident during the season. Seven injuries had a gradual onset (3.9%). Injury rates per 1000 hours are presented in Table 3.1. Male and female collegiate college players had a similar injury rate (10.9 vs11.3 injuries/1000 hours). Rugby (20.8 injuries/1000 hours) and soccer (19.5 injuries/1000 hours) had the highest injury rates. Injury rates were higher in matches than in training (33.3 vs 5.1 injuries/1000 hours).

Table 3. 1. Incidence Proportion and Injury Rates for various college players.

	Incidence Proportion	Exposure Hours Total	Match	Training	Total IR	Match IR	Training IR
Total (n=672)	.266 (.234-.301)	15615	3273	12342	10.8 (9.3-12.6)	33.3 (27.6-40.2)	5.1 (4.0-6.5)
				Gender			
Male (n=416)	.248 (.209-.291)	9312	1926	7386	10.9 (8.92-13.8)	34.8 (27.4-44.2)	4.6 (3.3-6.4)
Female (n=256)	.297 (.244-.356)	6303	1342	4956	11.3 (8.9-14.2)	31.2 (23.0-42.2)	5.9 (4.1-8.4)
				Sport			
Gaelic Football (n=299)	.291 (.242-.345)	7492	1523	5969	11.6 (9.4-14.3)	30.9 (23.2-41.1)	6.0 (4.4-8.4)
Male (n=180)	.261 (.202-.330)	4144	947	3197	11.1 (8.3-14.8)	28.5 (19.6-41.6)	5.6 (3.5-8.9)
Female (n=119)	.336 (.258-.425)	3348	576	2722	11.2 (9.0-16.6)	34.7 (22.4-53.8)	6.5 (4.1-10.3)
Hurling/ Camogie (n=223)	.148 (.107-.201)	5214	1171	4043	6.3 (4.5-8.9)	17.9 (11.7-27.5)	2.5 (1.3-4.6)
Male (n=138)	.138 (.090-.205)	3364	611	2753	5.7 (3.6-8.9)	22.9 (13.6-38.7)	2.5 (1.2-5.3)
Female (n=85)	.165 (.101-.258)	1850	560	1290	7.6 (4.5-12.8)	12.5 (6.0-26.2)	3.9 (1.6-9.3)
Soccer (n=69)	.319 (.221-.436)	1129	245	884	19.5 (12.8-29.6)	57.1 (33.8-96.5)	9.1 (4.5-18.1)
Male (n=47)	.319 (.204-.462)	776	156	620	19.3 (11.7-32.1)	57.5 (30.0-110.9)	8.1 (3.4-19.4)
Female (n=22)	.318 (.164-.527)	353	89	264	19.8 (9.5-41.6)	56.2 (23.4-135.0)	7.6 (1.9-30.3)
Rugby (n=81)	.457 (.353-.565)	1780	334	1446	20.8 (15.1-28.7)	71.9 (48.2-107.2)	8.3 (4.7-14.6)
Male (n=51)	.451 (.323-.586)	1028	212	816	22.4 (14.9-33.7)	80.2 (49.8-129.0)	12.3 (6.6-22.8)
Female (n=30)	.467 (.302-.639)	752	122	630	18.6 (11.0-31.4)	82.0 (44.1-152.3)	6.3 (2.4-16.9)

IR: injury rate per 1000 hours; n: sample size.

Lower extremity injuries accounted for 68.8% of all injuries in the college player in this study. The most prevalent injuries in collegiate Gaelic Football were hamstring strain (21.3%) and concussion (10.2%) (Table 3.2). However, in male Gaelic football, hamstring strain and ankle sprain injuries led to the greatest injury burden (59.4 and 38.1 days lost/1000 hours), while knee sprain and hamstring strains had the greatest burden in Ladies Gaelic football (84.8 and 50.2 days lost/1000 hours) (Table 3.3). Hurling/Camogie players predominantly sustained calf strains (15.2%) (Table 3.2), which also had the greatest burden (16.9 days lost/1000 hours) in males. However, adductor strains had the greatest burden in Camogie (41.6 days lost/1000 hours) (Table 3.3). Yet, hamstring strains had the largest burden of injury for males and females combined in Gaelic football (55.1 days lost/1000 hours) and hurling/Camogie (17.1 days lost/1000 hours) (Table 3.4). The most prevalent injuries in soccer were ankle sprains (18.2%) and hamstring strains (13.6%) which were both the injuries with the greatest injury burden in both males and females also. The most prevalent injuries sustained in Rugby were ankle sprains and shoulder sprains injuries (14.3%). The injury with the greatest burden in male Rugby was ankle sprains (280.2 days lost/1000 hours), while in female Rugby was hamstring strains (118.4 days lost/1000 hours) (Table 3.3). Concussion injury rates for matches and training combined were 0.8 and 1.0 injuries/1000 hours in males and females respectively, with match concussion injury rates of 3.6 and 3.7 injuries/1000 hours in males and females respectively. Males (22.1 days lost/1000 hours) had a slightly larger burden of injury than females (19.4 days lost/1000 hours).

Table 3. 2. Injury Proportion and Injury Rates of different injuries for different sports.

	Gaelic Football		Hurling/Camogie		Soccer		Rugby	
Body region	IP	IR	IP	IR	IP	IR	IP	IR
Foot								
Bone bruising	2.2 (.6-7.8)	0.3 (0.1-1.1)	0.0 (0.0-10.4)	-	0.0 (0.0-14.9)	-	0.0 (0.0-9.9)	-
Ligament sprain	0.0 (0.0-4.1)	-	3.0 (0.5-15.3)	0.2 (0.0-1.4)	4.5 (0.8-21.8)	0.9 (0.1-6.3)	0.0 (0.0-9.9)	-
Ankle								
Bone bruising	0.0 (0.0-4.1)	-	0.0 (0.0-10.4)	-	9.1 (2.5-27.3)	1.8 (0.4-7.1)	0.0 (0.0-9.9)	-
Ligament sprain	7.9 (3.9-15.4)	0.9 (0.4-2.0)	3.0 (0.5-15.3)	0.2 (0.0-1.4)	18.2 (7.3-38.5)	3.5 (1.3-9.4)	14.3 (6.3-29.4)	2.8 (1.2-6.7)
Tendinopathy	0.0 (0.0-4.1)	-	0.0 (0.0-10.4)	-	0.0 (0.0-14.9)	-	2.9 (0.5-14.5)	0.6 (0.1-4.0)
Shin								
Muscle contusion	1.1 (0.2-6.1)	0.1 (0.0-0.9)	6.1 (1.7-19.6)	0.4 (0.1-1.5)	0.0 (0.0-14.9)	-	0.0 (0.0-9.9)	-
Calf								
Muscle contusion	1.1 (0.2-6.1)	0.1 (0.0-0.9)	0.0 (0.0-10.4)	-	0.0 (0.0-14.9)	-	2.9 (0.5-14.5)	0.6 (0.1-4.0)
Muscle strain	5.6 (2.4-12.5)	0.7 (0.3-1.6)	15.2 (6.7-30.9)	1.0 (0.4-2.3)	4.5 (0.8-21.8)	0.9 (0.1-6.3)	8.6 (3.0-22.4)	1.7 (0.5-5.2)
Muscle tightness	2.2 (.6-7.8)	0.3 (0.1-1.1)	3.0 (0.5-15.3)	0.2 (0.0-1.4)	0.0 (0.0-14.9)	-	0.0 (0.0-9.9)	-
Knee								
Bone bruising	1.1 (0.2-6.1)	0.1 (0.0-0.9)	0.0 (0.0-10.4)	-	0.0 (0.0-14.9)	-	0.0 (0.0-9.9)	-
Joint dislocation	1.1 (0.2-6.1)	0.1 (0.0-0.9)	0.0 (0.0-10.4)	-	0.0 (0.0-14.9)		0.0 (0.0-9.9)	-
Meniscus	2.2 (.6-7.8)	0.3 (0.1-1.1)	0.0 (0.0-10.4)	-	0.0 (0.0-14.9)	-	0.0 (0.0-9.9)	-
Ligament sprain	4.5 (1.8-11.0)	0.5 (0.2-1.4)	3.0 (0.5-15.3)	0.2 (0.0-1.4)	9.1 (2.5-27.3)	1.8 (0.4-7.1)	2.9 (0.5-14.5)	0.6 (0.1-4.0)

Tendinopathy	2.2 (.6-7.8)	0.3 (0.1-1.1)	0.0 (0.0-10.4)	-	4.5 (0.8-21.8)	0.9 (0.1-6.3)	2.9 (0.5-14.5)	0.6 (0.1-4.0)
Anterior thigh								
Muscle Contusion	1.1 (0.2-6.1)	0.1 (0.0-0.9)	3.0 (0.5-15.3)	0.2 (0.0-1.4)	0.0 (0.0-14.9)	-	5.7 (1.6-18.6)	1.1 (0.3-4.5)
Ligament sprain	1.1 (0.2-6.1)	0.1 (0.0-0.9)	0.0 (0.0-10.4)	-	0.0 (0.0-14.9)	-	0.0 (0.0-9.9)	-
Muscle strain	3.4 (1.2-9.4)	0.4 (0.1-1.2)	0.0 (0.0-10.4)	-	0.0 (0.0-14.9)	-	0.0 (0.0-9.9)	-
Posterior thigh								
Muscle strain	21.3 (14.1-31.0)	2.5 (1.6-4.0)	6.1 (1.7-19.6)	0.4 (0.1-1.5)	13.6 (4.7-33.3)	2.7 (0.9-8.2)	8.6 (3.0-22.4)	1.7 (0.5-5.2)
Tendinopathy	1.1 (0.2-6.1)	0.1 (0.0-0.9)	3.0 (0.5-15.3)	0.2 (0.0-1.4)	0.0 (0.0-14.9)	-	0.0 (0.0-9.9)	-
Muscle tightness	1.1 (0.2-6.1)	0.1 (0.0-0.9)	0.0 (0.0-10.4)	-	0.0 (0.0-14.9)	-	0.0 (0.0-9.9)	-
Other	1.1 (0.2-6.1)	0.1 (0.0-0.9)	0.0 (0.0-10.4)	-	0.0 (0.0-14.9)	-	0.0 (0.0-9.9)	-
Groin								
Muscle strain	9.0 (4.6-16.7)	1.1 (0.5-2.1)	6.1 (1.7-19.6)	0.4 (0.1-1.5)	4.5 (0.8-21.8)	0.9 (0.1-6.3)	0.0 (0.0-9.9)	-
Tendinopathy	1.1 (0.2-6.1)	0.1 (0.0-0.9)	0.0 (0.0-10.4)	-	0.0 (0.0-14.9)	-	0.0 (0.0-9.9)	-
Hip								
Labrum	2.2 (.6-7.8)	0.3 (0.1-1.1)	0.0 (0.0-10.4)	-	0.0 (0.0-14.9)	-	0.0 (0.0-9.9)	-
Muscle strain	3.4 (1.2-9.4)	0.4 (0.1-1.2)	0.0 (0.0-10.4)	-	4.5 (0.8-21.8)	0.9 (0.1-6.3)	0.0 (0.0-9.9)	-
Tendinopathy	0.0 (0.0-4.1)	-	0.0 (0.0-10.4)	-	4.5 (0.8-21.8)	0.9 (0.1-6.3)	0.0 (0.0-9.9)	-
Muscle tightness	0.0 (0.0-4.1)	-	0.0 (0.0-10.4)	-	4.5 (0.8-21.8)	0.9 (0.1-6.3)	0.0 (0.0-9.9)	-
Neural compression	1.1 (0.2-6.1)	0.1 (0.0-0.9)	3.0 (0.5-15.3)	0.2 (0.0-1.4)	0.0 (0.0-14.9)	-	0.0 (0.0-9.9)	-
Muscle contusion	0.0	-	6.1	0.4	0.0	-	0.0	-

	(0.0-4.1)		(1.7-19.6)	(0.1-1.5)	(0.0-14.9)		(0.0-9.9)	
Ligament sprain	2.2 (.6-7.8)	0.3 (0.1-1.1)	0.0 (0.0-10.4)	-	0.0 (0.0-14.9)	-	2.9 (0.5-14.5)	0.6 (0.1-4.0)
Muscle strain	2.2 (.6-7.8)	0.3 (0.1-1.1)	3.0 (0.5-15.3)	0.2 (0.0-1.4)	0.0 (0.0-14.9)	-	0.0 (0.0-9.9)	-
Thoracic								
Muscle strain	1.1(0.2-6.1)	0.1(0.0-0.9)	6.1 (1.7-19.6)	0.4 (0.1-1.5)	0.0 (0.0-14.9)	-	2.9 (0.5-14.5)	0.6 (0.1-4.0)
Neck								
Neural compression	0.0(0.0-4.1)	-	3.0 (0.5-15.3)	0.2 (0.0-1.4)	0.0 (0.0-14.9)	-	0.0 (0.0-9.9)	-
Chest								
Bone bruising	0.0 (0.0-4.1)	-	3.0 (0.5-15.3)	0.2 (0.0-1.4)	0.0 (0.0-14.9)	-	0.0 (0.0-9.9)	-
Fracture	0.0 (0.0-4.1)	-	3.0 (0.5-15.3)	0.2 (0.0-1.4)	0.0 (0.0-14.9)	-	0.0 (0.0-9.9)	-
Head								
Concussion	10.1 (5.4-18.1)	1.2 (0.6-2.3)	6.1 (1.7-19.6)	0.4 (0.1-1.5)	0.0 (0.0-14.9)	-	11.4 (4.5-26.0)	2.2 (0.8-6.0)
Eye								
Contusion	0.0 (0.0-4.1)	-	0.0 (0.0-10.4)	-	4.5 (0.8-21.8)	0.9 (0.1-6.3)	0.0 (0.0-9.9)	-
Laceration	0.0 (0.0-4.1)	-	0.0 (0.0-10.4)	-	0.0 (0.0-14.9)	-	2.9 (0.5-14.5)	0.6 (0.1-4.0)
Shoulder								
Labrum	0.0 (0.0-4.1)	-	0.0 (0.0-10.4)	-	0.0 (0.0-14.9)	-	2.9 (0.5-14.5)	0.6 (0.1-4.0)
Ligament sprain	1.1 (0.2-6.1)	0.1 (0.0-0.9)	3.0 (0.5-15.3)	0.2 (0.0-1.4)	0.0 (0.0-14.9)	-	14.3 (6.3-29.4)	2.8 (1.2-6.7)
Muscle strain	0.0 (0.0-4.1)	-	3.0 (0.5-15.3)	0.2 (0.0-1.4)	4.5 (0.8-21.8)	0.9 (0.1-6.3)	11.4 (4.5-26.0)	2.2 (0.8-6.0)
Muscle tightness	1.1 (0.2-6.1)	0.1 (0.0-0.9)	0.0 (0.0-10.4)	-	0.0 (0.0-14.9)	-	2.9 (0.5-14.5)	0.6 (0.1-4.0)
Wrist								
Ligament sprain	0.0	-	3.0	0.2	0.0	-	0.0	-

	(0.0-4.1)		(0.5-15.3)	(0.0-1.4)	(0.0-14.9)		(0.0-9.9)	
Finger								
Ligament sprain	0.0 (0.0-4.1)	-	0.0 (0.0-10.4)	-	4.5 (0.8-21.8)	0.9 (0.1-6.3)	0.0 (0.0-9.9)	-
Thumb								
Bone bruising	1.1(0.2-6.1)	0.1 (0.0-0.9)	0.0 (0.0-10.4)	-	0.0 (0.0-14.9)	-	0.0 (0.0-9.9)	-
Ligament sprain	1.1 (0.2-6.1)	0.1 (0.0-0.9)	3.0 (0.5-15.3)	0.2 (0.0-1.4)	4.5 (0.8-21.8)	0.9 (0.1-6.3)	0.0 (0.0-9.9)	-

IP: incidence proportion; IR: injury rate per 1000 hours.

Table 3. 3. Burden of Injury for individual sports.

	Male Football	Female Football	Hurling	Camogie	Male Soccer	Female Soccer	Male Rugby	Female Rugby
Foot								
Bone bruising	4.8 (3.1-7.5)	6.3 (4.1-9.6)	-	-	-	-	-	-
Ligament sprain	-	-	12.5 (9.2-16.9)	-	24.5 (15.6-38.4)	-	-	-
Ankle								
Bone bruising	-	-	-	-	12.9 (6.9-24.0)	14.2 (5.9-34.0)	-	-
Ligament sprain	38.1 (32.6-44.6)	20.6 (16.3-26.1)	-	7.6 (4.5-12.8)	85.1 (66.8-108.3)	113.3 (83.1-154.5)	280.2 (249.6-314.5)	78.5 (60.8-101.3)
Tendinopathy	-	-	-	-	-	-	29.2 (20.4-41.7)	-
Shin								
Muscle contusion	1.9 (1.0-3.9)	-	-	2.2 (.8-5.8)	-	-	-	-
Calf								
Muscle contusion	1.2 (.5-2.9)	-	4.2 (2.5-7.0)	-	-	-	-	37.2 (25.7-53.9)
Muscle strain	15.2 (11.9-19.5)	6.6 (4.3-10.0)	16.9 (13.1-22.0)	-	-	79.3 (54.8-114.9)	60.3 (47.0-77.4)	-
Muscle tightness	3.4 (2.0-5.7)	0.9 (.3-2.8)	-	2.7 (1.1-6.5)	-	-	-	-
Knee								
Joint dislocation	-	35.8 (30.0-42.9)	-	-	-	-	-	-
Meniscus	13.3 (10.2-17.3)	-	-	-	-	-	-	-
Ligament sprain	4.8 (3.1-7.5)	84.8 (75.5-95.3)	-	5.4 (2.9-10.0)	7.7 (3.5-17.2)	-	-	-
Tendinopathy	4.3 (2.7-6.9)	7.2 (4.8-10.7)	-	-	33.5 (22.8-49.2)	-	16.5 (10.3-26.6)	-

Anterior thigh								
Muscle Contusion	4.1 (2.6-6.6)	1.5 (.6-3.6)	0.3 (.0-2.1)	-	-	-	10.7 (5.9-19.3)	-
Muscle strain	-	14.3 (10.8-19.0)	-	-	-	-	-	-
Posterior thigh								
Muscle strain	59.4 (52.4-67.3)	50.2 (43.1-58.4)	13.7 (10.2-18.3)	23.2 (17.2-31.3)	74.7 (57.8-96.7)	102.0 (73.6-141.4)	-	118.4 (96.1-145.7)
Tendinopathy	-	11.9 (8.8-16.3)	8.6 (6.0-12.4)	-	-	-	-	-
Muscle tightness	1.2 (.5-2.9)	-	-	-	-	-	-	-
Other	1.4 (.7-3.2)	-	-	-	-	-	-	-
Groin								
Muscle strain	33.3 (28.2-39.3)	13.4 (10.0-18.0)	-	41.6 (33.3-52.0)	37.4 (26.0-53.8)	-	-	-
Tendinopathy	-	11.9 (8.8-16.3)	-	-	-	-	-	-
Hip								
Labrum	8.4 (6.1-11.8)	9.0 (6.3-12.8)	-	-	-	-	-	-
Muscle strain	-	23.6 (18.9-29.4)	-	-	27.1 (17.6-41.5)	-	-	-
Buttock								
Muscle tightness	-	-	-	-	-	28.3 (15.2-52.7)	-	-
Lumbar								
Muscle contusion	-	-	5.1 (3.1-8.1)	-	-	-	-	-
Ligament sprain	5.3 (3.5-8.1)	11.9 (8.8-16.3)	-	-	-	-	19.5 (12.6-30.2)	-
Muscle strain	13.0 (10.0-17.0)	-	-	13.5 (9.1-20.0	-	-	-	-

Fracture	-	13.4 (10.0-18.0)	-	16.8 (11.8-23.8)	-	-	-	-
Thoracic								
Muscle strain	-	6.3 (4.1-9.6)	8.6 (6.0-12.4)	-	-	-	8.8 (4.6-16.8)	-
Neck								
Neural compression	-	-	-	14.6 (10.0-21.3)	-	-	-	-
Chest								
Bone bruising	-	-	10.7 (7.7-14.8)	-	-	-	-	-
Fracture	-	-	12.5 (9.2-16.9)	-	-	-	-	-
Head								
Concussion	23.6 (19.4-28.8)	24.8 (20.0-30.7)	5.1 (3.1-8.1)	9.7 (6.1-15.4)	-	-	88.5 (72.1-108.7)	27.9 (18.2-42.8)
Eye								
Contusion	-	-	-	-	12.9 (6.9-24.0)	-	-	-
Laceration	-	-	-	-	-	-	-	6.6 (2.8-16.0)
Shoulder								
Ligament sprain	-	-	-	21.6 (15.9-29.5)	-	-	108.0 (89.6-130.1)	35.9 (24.6-52.4)
Muscle strain	-	-	6.2 (4.1-9.6)	-	-	-	101.2 (83.5-122.6)	42.6 (30.1-60.2)
Muscle tightness	1.4 (.7-3.2)	0.3 (.0-2.1)	-	-	-	-	4.9 (2.0-11.7)	-
Wrist								
Ligament sprain	-	-	5.9 (3.8-9.2)	-	-	-	-	-
Finger								
Ligament sprain	-	-	-	-	9.0 (4.3-18.9)	-	-	16.0 (9.1-28.1)
Fracture	-	-	-	-	-	-	24.3	-

							(16.4-36.0)	
Thumb								
Bone bruising	-	6.3	0.6	-	-	-	-	-
		(4.1-9.6)	(.1-2.4)					
Ligament sprain	-	1.5	-	-	-	56.7	-	-
		(.6-3.6)				(36.6-87.8)		

Injury burden: days absent per 1000 hours.

Table 3. 4. Total days off per injury and injury burden for the different sports male and female combined.

Body region	Gaelic football		Hurling/Camogie		Soccer		Rugby	
	Total days off per injury	**Injury Burden**	**Total days off per injury**	**Injury Burden**	**Total days off per injury**	**Injury Burden**	**Total days off per injury**	**Injury Burden**
Foot								
Bone bruising	41	5.5 (4.0-7.4)	-	-	-	-	-	-
Ligament sprain	-	-	42	8.1 (6.0-10.9)	19	16.8 (10.7-26.4)	-	-
Ankle								
Bone bruising	-	-	-	-	15	13.33 (8.0-22.0)	-	-
Ligament sprain	227	30.3 (26.6-34.5)	14	2.7 (1.6-4.5)	106	93.9 (77.6-113.6)	347	194.9 (175.5-216.6)
Tendinopathy	-	-	-	-	-	-	30	16.9 (11.8-24.1)
Shin								
Muscle contusion	8	1.1 (0.5-2.1)	14	2.7 (1.6-4.5)	-	-	-	-
Calf								
Muscle contusion	5	0.7 (0.3-1.6)	-	-	-	-	28	15.7 (10.9-22.8)
Muscle strain	85	11.3 (9.2-14.0)	57	10.9 (8.4-14.2)	28	24.8 (17.1-36.0)	62	34.8 (27.2-44.7)
Muscle tightness	18	2.4 (1.5-3.8)	5	1.0 (0.4-2.3)	-	-	-	-
Knee								
Bone bruising	14	1.9 (1.1-3.2)	-	-	-	-	-	-
Joint dislocation	120	16.0 (13.4-19.2)	-	-	-	-	-	-
Meniscus	55	7.3 (5.6-9.6)	-	-	-	-	-	-

Ligament sprain	304	40.6 (36.3-45.4)	10	1.9 (1.0-3.6)	6	5.3 (2.4-11.8)	-	-
Tendinopathy	38	5.1 (3.7-7.0)	-	-	26	23.0 (15.7-33.9)	17	9.6 (5.9-15.4)
Anterior thigh								
Muscle Contusion	5	0.7 (0.3-1.6)	1	0.2 (0.0-1.4)	-	-	11	6.2 (3.4-11.2)
Ligament sprain	17	2.3 (1.4-3.7)	-	-	-	-	-	-
Muscle strain	48	6.4 (4.8-8.5)	-	-	-	-	-	-
Posterior thigh								
Muscle strain	414	55.3 (50.2-60.8)	89	17.1 (13.9-21.0)	94	83.3 (68.1-102.0)	89	50.0 (40.6-61.5)
Tendinopathy	40	5.3 (3.9-7.3)	29	5.6 (3.9-8.0)	-	-	-	-
Muscle tightness	5	0.7 (0.3-1.6)	-	-	-	-	-	-
Other	6	0.8 (0.4-1.8)	-	-	-	-	-	-
Groin								
Muscle strain	183	24.4 (21.1-28.2)	77	14.8 (11.8-18.5)	29	25.7 (17.9-37.0)	-	-
Tendinopathy	40	5.3 (3.9-7.3)	-	-	-	-	-	-
Hip								
Labrum	65	8.7 (6.8-11.1)	-	-	-	-	-	-
Muscle strain	79	10.5 (8.5-13.1)	-	-	21	18.6 (12.1-28.6	-	-
Buttock								
Muscle tightness	-	-	-	-	10	8.9 (4.8-16.5)	-	-
Lumbar								
Neural compression	45	6.0	31	5.9	-	-	-	-

		(4.5-8.0)		(4.2-8.5)				
Muscle contusion	-	-	17	3.3 (2.0-5.2)	-	-	-	-
Ligament sprain	62	8.3 (6.5-10.6)	-	-	-	-	20	11.2 (7.2-17.4)
Muscle strain	54	7.2 (5.5-9.4)	25	4.8 (3.2-7.1)	-	-	-	-
Thoracic								
Muscle strain	21	2.8 (1.8-4.3)	29	5.6 (3.9-8.0)	-	-	9	5.1 (2.6-9.7)
Neck								
Neural compression	-	-	27	5.2 (3.6-7.6)	-	-	-	-
Chest								
Bone bruising	-	-	36	6.9 (5.0-9.6)	-	-	-	-
Fracture	-	-	42	8.1 (6.0-10.9)	-	-	-	-
Head								
Concussion	181	24.2 (20.9-27.9)	35	6.7 (4.8-9.3)	-	-	112	62.9 (52.3-75.7)
Eye								
Contusion	-	-	-	-	10	8.9 (4.8-16.5	-	-
Laceration	-	-	-	-	-	-	5	2.8 (1.2-7.7)
Shoulder								
Labrum	-	-	-	-	-	-	-	-
Ligament sprain	-	-	40	7.7 (5.6-10.5)	-	-	138	77.5 (65.6-91.6)
Muscle strain	-	-	21	4.0 (2.6-6.2)	-	-	136	76.4 (64.6-90.4)
Muscle tightness	7	0.9 (0.4-2.0)	-	-	-	-	5	2.8 (1.2-6.7)
Wrist								

Ligament sprain	-	-	20	3.8 (2.5-5.9)	-	-	-	-
Finger								
Ligament sprain	-	-	-	-	7	6.2 (3.0-13.0)	12	6.7 (3.8-11.9)
Fracture	-	-	-	-	-	-	25	14.0 (9.5-20.8)
Thumb								
Bone bruising	21	2.8 (1.8-4.3)	-	-	-	-	-	-
Ligament sprain	5	0.7 (0.3-1.6)	-	-	20	17.7 (11.4-27.5)	-	-

Injury burden: days absent per 1000 hours

Injuries were primarily acute (73.2%), with just over a quarter of injuries being insidious in nature. The type of injuries were predominantly new injuries (79.3%) (Table 3.5). Recurrent injuries were seen more frequently in females than male college players (22.4% vs 19.4%). Muscles (53.1%) and ligaments (24.0%) were the predominantly injured tissue, with males sustaining more muscular injuries than females (56.3% vs 48.7%) but fewer ligamentous injuries (21.4% vs 27.6%). Strains (40.2%) and sprains (23.5%) account for the greatest type of injuries. Strains and sprains had the greatest burden than any other injury type (105.7 and 89.5 days lost/1000 h), respectively. Contusions (11.0% vs 0.0%) and concussions (11.0% vs 2.0%) were more frequent in match play than in training. Four injuries in total required surgery (2.2%).

Injuries were predominantly non-contact (57.5%), with injuries involving contact slightly higher in males than females (43.7% vs 40.8%). Injuries sustained in matches were predominantly contact injuries (55.0%); however, during training non-contact injuries (74.6%) were predominant (Table 3.5). Sprinting (27.4%), being tackled (10.6%), tackling (9.5%), and turning (8.9%) were the most frequent mechanisms of injury. Sprinting was the most common mechanism of injury in Gaelic football (33.3%), hurling/Camogie (27.3%) and soccer (22.7%) but only second most common in Rugby (15.8%), with the tackle (39.5%) the most common mechanism of injury in Rugby. Sprinting carried a similar risk in both training (25.4%) and matches (27.5%); however, the tackle was a greater risk in matches (27.5%) rather than in training (10.2%). Foul play was involved in 9.5% of injuries.

Injury severity showed that most injuries were moderate (52.7%), followed by severe (32.0%) (Table 3.5). The mean time loss due to injury for male and female college players combined.

Table 3. 5. Onset, New and Recurrent Injuries, Tissue Injured and Type, Contact, Mechanism of Injury, and Severity of Injury.

	Total % (95% confidence interval)	**Male % (95% confidence interval)**	**Female % (95% confidence interval)**
Onset			
Acute	73.2 (66.3-79.1)	72.8 (63.5-80.5)	73.3 (62.8-82.3)
Insidious	26.8 (20.9-33.7)	27.2 (19.5-36.5)	26.3 (17.7-37.2)
New and recurrent injuries			
New injury	79.3 (72.8-84.6)	80.6 (71.9-87.1)	77.6 (67.1-85.5)
Early recurrence	6.7 (3.9-11.4)	5.8 (2.7-12.1)	7.9 (3.7-16.2)
Late recurrence	6.1 (3.5-10.7)	5.8 (2.7-12.1)	6.6 (2.8-14.5)
Persistent/ recurring	7.8 (4.7-12.7)	7.8 (4.0-14.6)	7.9 (3.7-16.2)
Tissue			
Ligament	24.0 (18.4-30.8)	21.4 (14.5-30.2)	27.6 (18.8-38.6)
Muscle	53.1 (45.8-60.2)	56.3 (46.7-65.5)	48.7 (37.8-59.7)
Bone	6.1 (3.5-10.7)	6.8 (3.3-13.4)	5.3 (2.1-12.8)
Tendon	5.0 (2.7-9.3)	5.8 (2.7-12.1)	3.9 (1.4-11.0)
Nerve	1.7 (0.6-4.8)	0.0 (0.0-3.6)	3.9 (1.4-11.0)
Meniscus	1.1 (0.3-4.0)	1.9 (0.5-6.8)	0.0 (0.0-4.8)
Labrum	1.7 (0.6-4.8)	1.0 (0.2-5.3)	2.6 (0.7-9.1)
Type			
Sprain	23.5 (17.9-30.2)	21.4 (14.5-30.2)	26.3 (17.7-37.2)
Strain	40.2 (33.3-47.5)	41.7 (32.7-51.4)	38.2 (28.1-49.4)
Contusion	6.7 (3.9-11.4)	7.8 (4.0-14.6)	5.3 (2.1-12.8)
Tendinopathy	5.0 (2.3-8.6)	5.8 (2.7-12.1)	3.9 (1.4-11.0)
Fracture	1.1 (0.3-4.0)	1.9 (0.5-6.8)	0.0 (0.0-4.8)
Dislocation	0.6 (0.1-3.1)	0.0 (0.0-3.6)	1.3 (.02-7.1)
Laceration	0.6 (0.1-3.1)	0.0 (0.0-3.6)	1.3 (0.2-7.1)
Concussion	7.3 (4.3-12.0)	6.8 (3.3-13.4)	7.9 (3.7-16.2)
Bone bruise	4.5 (2.3-8.6)	4.9 (2.1-10.9)	3.9 (1.4-11.0)
Muscle tightness	5.0 (2.7-9.3)	4.9 (2.1-10.9)	5.3 (2.1-12.8)
Neural	1.7 (0.6-4.8)	0.0 (0.0-3.6)	3.9 (1.4-11.0)
Cartilage/labrum	2.8 (1.2-6.4)	2.9 (1.0-8.2)	2.6 (0.7-9.1)
Other	1.1 (0.3-4.0)	1.9 (0.5-6.8)	0.0 (0.0-4.8)
Contact			
Contact	42.5 (35.5-49.8)	43.7 (34.5-53.3)	40.8 (30.4-52.0)
Non-contact	57.5 (50.2-64.5)	56.3 (46.7-65.5)	59.2 (48.0-69.6)
Mechanism			
Jumping/catching	5.6 (3.9-11.4)	5.8 (2.7-12.1)	7.9 (3.7-16.2)
Landing	6.1 (3.5-10.7)	6.8 (3.3-13.4)	5.3 (2.1-12.8)
Turning	8.9 (5.6-14.0)	7.8 (4.0-14.6)	10.5 (5.4-19.4)
Running/sprinting	27.4 (21.4-34.3)	27.2 (19.5-36.5)	27.6 (18.8-38.6)
Kicking	7.8 (4.7-12.7)	9.7 (5.4-17.0)	5.3 (2.1-12.8)
Diving	0.6 (0.1-3.1)	0.0 (0.0-3.6)	1.3 (0.2-7.1)
Hand pass	0.6 (0.1-3.1)	1.0 (0.2-5.3)	0.0 (0.0-4.8)
Stopping	1.1 (0.3-4.0)	1.0 (0.2-5.3)	1.3 (0.2-7.1)
Falling	3.4 (1.5-7.1)	1.9 (0.5-6.8)	5.3 (2.1-12.8)
Tackling	9.5 (6.0-14.7)	8.7 (4.7-15.8)	10.5 (5.4-19.4)
Being tackled	10.6 (6.9-16.0)	12.6 (7.5-20.4)	7.9 (3.7-16.2)
Blocking	1.7 (0.6-4.8)	1.9 (0.5-6.8)	1.3 (0.2-7.1)
Hooking	0.6 (0.1-3.1)	1.0 (0.2-5.3)	0.0 (0.0-4.8)
Pushing/shoving	2.8 (1.2-6.4)	1.9 (0.5-6.8)	3.9 (1.4-11.0)

No specific activity	12.3 (8.3-17.9)	12.6 (7.5-20.4)	11.8 (6.4-21.0)
Severity			
Minor	15.4 (10.7-21.6)	12.4 (7.2-20.4)	18.1 (10.9-28.5)
Moderate	52.7 (45.2-60.0)	56.7 (46.8-66.1)	48.6 (37.4-59.9)
Severe	32.0 (25.4-39.3)	30.9 (22.6-40.7)	33.3 (23.5-44.8)

3.4 Discussion

This study aimed to prospectively establish the epidemiology of injury in collegiate players in the four most popular collegiate Irish sports. One in four college players sustained an injury during the season. The injury rate for collegiate college players across all sports was 10.8 injuries/1000 hours, with a match injury rate over six times higher than the training injury rate. Injury rates were similar for males (10.9/1000 hours) and females (11.3/1000 hours). An injury substantially impacts player availability, with 84.7% of injuries leading to more than seven days absent from sport. Due to the high injury rates and injury severity, appropriate injury prevention prescribed to and adhered to by the college player is recommended. The collegiate sports needs to develop a comprehensive injury prevention strategy that could include elements of the GAA15, the FIFA 11+ and the Activate Injury Prevention Warm-up.

Total injury rates in Gaelic football were similar for males (11.1/1000 hours) and females (11.2/1000 hours). This is in agreement with previous male collegiate Gaelic football but less than female collegiate Gaelic football (17.9/1000 hours) (O'Connor et al., 2016; O'Connor et al., 2021). In the current study, training injury rates for both males and females (5.6/1000 h vs 6.5/1000 h respectively) are similar to previous collegiate research in both males and females (7.3 and 7.9 injuries/1000 hours respectively) (O'Connor et al., 2016; O'Connor et al., 2021). In line with previous research, the match injury rate was higher in females than males (34.7 vs 28.5 injuries/1000 hours). As injury rates are higher in females, injury prevention exercise programmes such as the GAA15 (a sport-specific injury prevention exercise programme specific to Gaelic games derived from the FIFA 11+) may need to be implemented by the female Gaelic footballer to try and reduce injuries. Collegiate hurlers (22.9 injuries/1000 hours) and Camogie players (12.5 injuries/1000 hours) had a lower match injury rate than elite hurlers (102.5 and 61.75 injuries/1000 hours) and Camogie players (26.4 injuries/1000 hours) (Murphy et al., 2010; Blake et al., 2014; Buckley and Blake, 2018). Possible explanations for the higher injury rate at the elite level are higher intensity, skill better conditioned and, therefore, the ability to generate higher speeds and forces (DiStefano et al., 2018).

Injury rates did not differ for male and female soccer (19.3 vs 19.8 injuries/1000 hours) in this study. This has also been noted in NCAA soccer, where it was found that injury rates in male and female soccer were also similar (8.1 and 8.4 injuries/1000 athlete exposures) (Roos et al., 2016). However, when calculated per athlete exposure, this current study had an injury rate of 20.7 and 21.7 injuries/1000 athlete exposures, male and female respectively. This is much higher than previously reported in the NCAA. However, the high injury rates in this study highlight the need for injury prevention, such as the FIFA 11+, to be implemented in the Irish college player. The FIFA 11+ has effectively reduced injury rates and time loss in male US college players (Silvers-Granelli et al., 2015).

Rugby had the highest match injury rate of all collegiate sports in this study, most likely due to the increased physicality of Rugby. The Irish collegiate Rugby player injury rate was substantially higher than previously reported in collegiate US male and female Rugby (16.9 and 17.1 injuries/1000 hours) (Kerr et al., 2008) and Irish amateur male and female rugby players (49.1 and 35.6/1000 hours respectively) (Yeomans et al., 2021). An explanation for the increased injury rate in the Irish college player may be that the Irish college player may be playing with numerous other rugby teams concurrently outside of the collegiate level (e.g., club, provincial, national). This may lead to higher cumulative workloads and a potential for greater injury rates, as seen in male adolescent Gaelic footballers (O'Keeffe et al., 2020). Furthermore, the US study by Kerr et al. (2008) was completed over 15 years ago, and injury rates may have increased in recent years. For example, one study on youth rugby saw an increase in injury rate (13.5-27.7 injuries/1000 hours) each year from 2013 to 2016 (Sewry et al., 2018).

The negative impact of injuries in this study was substantial, with over half the injuries of moderate severity, almost a third being severe, leading to greater than 28 days' time loss and 85.0% of injuries leading to a time loss from sport greater than seven days. Thus, there is a clear need for injury prevention exercise programmes to be implemented in Irish collegiate college players to reduce the number and severity of injuries. It is important to disseminate this information to coaches and college players, as the collegiate season in Ireland is short and with 32.0% of injuries having a time loss greater than 28 days, a college player may miss a significant part of the season. In addition, minimising injury severity is essential, as almost 25.0% of dropout from sport in Ireland is due to injury (Lunn et al., 2013).

Injuries predominantly occurred to the lower extremity for Irish college players (68.8%). This is similar to Gaelic football, hurling/Camogie and soccer (68.3-75.9%) (O'Connor et al., 2016; O'Connor et al., 2021; Blake et al., 2014; Buckley and Blake, 2018; Roos et al., 2016); however, injuries to the lower extremity in Rugby are less common (35.5-43.1%) (Kerr et al., 2008). The posterior thigh was the most commonly injured body region for males (17.5%) and females (18.4%). In Gaelic football, a hamstring muscle strain accounted for 21.3% of all injuries. Previous research in elite male Gaelic football reports that hamstring injuries account for up to 21.3% of injuries over eight years, and similarly, in Ladies collegiate Gaelic football, hamstring injuries accounted for 21.5% of injuries (O'Connor et al., 2020; Roe et al., 2018). Hamstring strains (13.7-118.4 days absent/1000 hours) were one of the top two injuries with the greatest burden for all sports except male Rugby, and was the greatest burden of injury in Gaelic games sports when male and female combined. Previously, males had a lower injury burden than females for hamstring injuries at the collegiate Gaelic football level (38.6 and 66.1 days absent/1000 hours, respectively) (O'Connor et al., 2016; O'Connor et al., 2021). There is previously no research on the burden of hamstring injuries in hurling and Camogie; however, the thigh has the greatest injury proportion in both hurling and Camogie (Murphy et al., 2010; Buckley and Blake, 2018). Again, there is no previous research reporting burden at the collegiate level in both soccer and Rugby; however, in sub-elite Australian male soccer, the hamstring (38 days absent/1000 hours) had the greatest burden (Whalan et al., 2019). With the high incidence and burden of hamstring strain injuries, injury prevention exercise programmes should incorporate the Nordic hamstring exercise and sprint exposure, previously described as a vaccine for hamstring injuries (Edouard et al., 2019; Al Attar et al., 2017). The Nordic hamstring exercise can decrease the risk of hamstring injuries by up to 51.0%, and players exposed to a moderate amount of sprint exposure of velocities greater than 95% of maximum velocity had a reduced risk of a hamstring injury, compared to players exposed to lower velocities (Al Attar et al., 2017; Malone et al., 2017). Hence, it is essential to provide this information to coaches so that they can implement injury prevention exercises in their training.

The ankle joint was the next most frequently injured body region for males (11.7%) and females (10.5%), with injury proportion ranging from 3.0 to 18.2% across the different sports. Ankle injuries had a large burden of injury, particularly in soccer (85.1 and 113.3 days absent/1000 hours) and Rugby (280.2 and 78.5 days absent/1000 hours). This is much more than previously reported in sub-elite Australian male soccer (33 days/1000 hours) (Whalan et al., 2019). As ankle sprain injuries lead to a large burden, neuromuscular training programmes incorporating balance and proprioception, such as the FIFA 11+, should be introduced as part of the warm-up. The FIFA 11+ effectively limits injuries and increases performance (Bizzini and Dvorak, 2015). It is imperative for coaches to be educated on the use and benefits of and how to deliver injury prevention exercise programmes in their trainings.

Although knee sprains did not have a large proportion of injury (2.9-9.1%), their burden of injury was found to be substantial, particularly in Ladies Gaelic football (84.8 days absent/1000 hours). This is less than previously reported in collegiate Ladies Gaelic football (106.5 days absent/1000 hours) (O'Connor et al., 2021). The female player is twice as likely to sustain an ACL injury, and the female college player is a vulnerable group for this injury (Beynnon et al., 2014). With the high burden of injury, especially in Ladies Gaelic football, injury prevention should incorporate neuromuscular control, landing mechanics and increasing lower extremity muscle strength to try to reduce the impact of this type of injury.

Although calf (4.5-15.2%) and groin strains (4.5-9.0%) occur less frequently than hamstring strains and ankle sprains, they do also have a large injury burden. Calf injuries had a particularly high burden of injury in female soccer (79.3 days absent/1000 hours) and male Rugby (60.3 days absent/1000 hours). It must be noted that training and matches were occasionally played on Astroturf, which may have an impact as it has previously been reported that ankle and Achilles injuries have a statistically higher incidence on artificial turf (Calloway et al., 2019).

Groin strains had a large burden in male Gaelic football, Camogie players and male soccer players (33.3-41.6 days absent/1000 hours). This is more than previously reported in male collegiate Gaelic football and soccer (O'Connor et al., 2016; Whalan et al., 2019). As all these are multidirectional sports, cutting may put the college player at increased risk of injury. Incorporating the Copenhagen exercise into the warm-up cool-down should be considered, as its incorporation has been found to reduce the risk of groin strains by up to 41.0% (Harøy et al., 2019).

Concussions ranged from 0.0 to 11.4% of all injuries in the different sports. Concussion match injury rates were similar for both males and females, similar to Irish amateur Rugby (5.6 and 5.5 injuries/1000 hours) (Yeomans et al., 2021). However, a large injury burden was noted, particularly in Rugby players (88.5 days absent/1000 hours male: 27.9 days absent/1000 hours female). The burden of concussion injuries in this study for Rugby is much less than previously reported in professional Rugby union in Ireland (226 and absent/1000 hours) (Cosgrave and Williams, 2019). This may be attributed to the increased awareness of concussion at the elite level and the increased physicality at that level. Males had a larger burden of injury from a concussion, which is in contrast to previous research where females are generally at a higher risk of concussion (Koerte et al., 2020). Both males and females in this study had a longer recovery time than what has been previously recommended of 10 days by the Berlin consensus statement on concussion (McCrory et al., 2017). Players and coaches should be educated on the signs and symptoms, and how to manage best and rehabilitate concussions. Concussions are complex, resulting in varying symptoms and problems, but most recover in 14 days (McCrory et al., 2017). A short period of rest, followed by progressively becoming more active while staying below symptom exacerbation, is recommended following a concussion (Schneider et al., 2017).

Injuries were predominantly non-contact (57.5%), which is slightly higher than previously reported in Gaelic football, Camogie, soccer and Rugby (19.0-52.1%) (O'Connor et al., 2016; Buckley and Blake, 2018; Marr et al., 2014; Kerr et al., 2008). Sprinting accounted for 27.4% of injuries and may be related to the high incidence of hamstring injuries across the various sports. High-speed running puts an increased load on the hamstrings during the terminal swing phase, making them more susceptible to injury (Chumanov et al., 2011). Previous research has indicated that 73.4% of hamstring injuries occur during sprinting (Roe et al., 2016). When combined, turning and landing accounted for 15.0% of all injuries. This is similar to those previously reported in Gaelic sports (13.9-21.8%) (Blake et al., 2014; O'Connor et al., 2016; O'Connor et al., 2021). However, this is more than in previous collegiate Rugby, where turning injuries accounted for between 2.2 and 6.9% of injuries in games and training (Kerr et al., 2008). Due to a large amount of turning and landing injuries, emphasis should focus on balance, landing and change of direction technique as part of injury prevention strategies to reduce the risk of these non-contact injuries. The tackle contributed to more injuries in matches than in training, highlighting the competitiveness, unpredictability and increased physicality that come with games and the more controlled environment at training. It may be of some value to include proper tackling techniques in injury prevention exercise programmes and adequate strength and conditioning so that tackle technique will not be affected by fatigue (Yeomans et al., 2021).

There are several limitations to the current study. Firstly, data was collected in a single third-level institution. Future research should incorporate more institutions from around the country to improve the generalizability of the findings. It is unknown if college players played more than one sport or more than one team in the study. However, college players typically play and specialise solely in one sport at the collegiate level. Due to the Covid-19 pandemic, the collegiate season was reduced by up to 4 weeks for some sports, and as a result, there were slightly fewer matches and training than in a typical academic year. As a result, injury rates may be lower than usual due to matches being cancelled, especially towards the final stages of the season, where recurrent injury rates are higher (Hägglund et al., 2016). The injury report form was initially developed for use in Gaelic games and, therefore, may not capture mechanisms more specific to other sports, such as scrums in Rugby. Therefore, future studies should utilise an injury report form more suitable for all sports. As no data was collected on whether the injury occurred on the Astroturf or regular grass, future research should include this. All players were playing at the collegiate level, but no analysis was completed on the specific grades within the collegiate level (e.g. freshers, seniors or divisional status of the team). Further research should differeciate between the different grades.

3.5 Conclusion

Injuries are frequent in collegiate sports, with one in four sustaining an injury during the academic year, and players regularly require greater than seven days absent from sports following injury. From our findings, all the sports in this study resulted in the Irish college player having similar injury locations and burdens. However, injury prevention exercise programmes should be sport specific to help with compliance. Gaelic football, hurling/Camogie, soccer and Rugby injury prevention should focus on the lower extremity, with a particular emphasis on hamstring and ankle injuries due to the burden of these injuries. The GAA15 and the FIFA 11+ incorporate the Nordic hamstring exercise and proprioceptive exercises; however, they must be regularly implemented in order to be effective. Injury prevention in Rugby should include proper tackling technique, while the Ladies Gaelic footballer needs to incorporate knee strengthening and landing exercises due to the high burden of knee sprains in the sport. The high injury rate and burden of hamstring injuries reported in this study indicate the need for further implementation research to maximise injury prevention exercise programme uptake by Irish collegiate college player teams.

Link to Chapter 4

From Chapter 3, it was found that injuries are an issue in all codes of Gaelic games and result in a significant time loss. Gaelic games are the most popular sports in Ireland. The hamstring muscle was the most predominant location of an injury and had the largest burden of injury amongst college Gaelic games players. In Gaelic games, one in four injuries occurred while the player was sprinting, which could explain the high proportion of hamstring injuries in this study. Previous research suggests that hamstring injuries primarily occur during the terminal swing phase of high-speed running when the hamstrings work eccentrically to slow down the extending shank. It is critical that measures are developed and introduced to reduce the number of hamstring injuries in Gaelic games, leading to greater player availability, increased team success, and reduced dropout from sport. The second stage of the TRIPP framework requires an understanding of the risk factors for injury. Research on hamstring injury risk factors in Gaelic games has been limited to date, with few studies investigating hamstring flexibility and eccentric strength and no studies on high-speed running exposure.

Chapter 4 aims to investigate if preseason screening of performance tests can identify Gaelic football players at risk of a hamstring injury. Non-modifiable risk factors such as previous injury and increased age are well established as having a strong association with hamstring injury risk. However, performance tests such as eccentric hamstring strength, ankle dorsiflexion range of motion, and jump height on the countermovement jump have mixed results in other sports, and only eccentric strength has been assessed in one study in Gaelic footballers. Similarly, most research has only investigated risk factors at one-time point in the season (primarily preseason). Risk factors are proposed to be dynamic and change after each exposure. Therefore we aimed to monitor these risk factors on a weekly basis. High-speed running exposure, particularly spikes in high-speed running volumes has been established as a risk factor for hamstring injury in AFL. However, this has yet to be investigated in the Gaelic footballer. Therefore, we aimed to determine prospectively if high-speed running exposure differs between injured and uninjured players and establish any differences amongst injured players at different time points of the season.

Chapter 4 Study 2 – Do High-Speed Running Volumes and Performance Tests Differ on the Week of Injury for Injured and Uninjured Gaelic Footballers?

4.1 Introduction

Gaelic football is a native Irish sport governed by the Gaelic Athletic Association (GAA). While it is an amateur sport, elite inter-county players practise like professional players, with players being required to attend pitch-based sessions up to three times a week and gym-based resistance-training sessions twice a week, respectively, along with other squad meetings (Beasley, 2015). Gaelic football is a multidirectional sport that calls for players to engage in a large amount of unpredictable, high-intensity activity (Shovlin et al., 2018). Gaelic footballers cover an average of 8889m in a match (Malone et al., 2017) or 116m per minute (Malone et al., 2016), at which between 11.8-17.6% is at high-speed running, defined as greater than 17 km/h (McGahan et al., 2020). Due to the nature of the game and the physical demands placed on the players, injury is common (O'Malley et al., 2014). In a recent systematic review and meta-analysis, injury rates in elite Gaelic football were found to be high, with 55.9 injuries occurring every 1000 hours of match play (Dekkers et al., 2022). This is higher than both male club (51.2 injuries/1000 hours) and collegiate Gaelic football (25.1 injuries/1000 hours), indicating that injuries are more of an issue in the elite game (Wilson et al., 2007; O'Connor et al., 2016). Similarly, this is higher than the match injury rate of professional soccer (López-Valenciano et al., 2020; Ekstrand et al., 2021). Hamstring injury rates are 2.2 injuries/1000 hours and are seven times higher in matches (8.4 injuries/1000 hours) than in training, with hamstring injuries the predominant time loss injury location (31.1%) (Roe et al., 2016). Hamstring injuries can significantly impact teams, as each year elite teams can expect to have nine hamstring injuries with a mean time loss of 26 days per injury and 79% of injuries lasting longer than seven days (Roe et al., 2016). Only two studies have reported injury burden in male Gaelic footballers (Roe et al., 2016; Teahan et al., 2021). Hamstring injury burden was high in elite footballers (57.2 days absent per 1000 hours) (Roe et al., 2016). Hamstring injuries were the greatest burden of all injuries in male collegiate Gaelic footballers (59.4 days absent per 1000 hours) (Teahan et al., 2021). Three-quarters of hamstring injuries in Gaelic football occur while the player is sprinting (73.4%) (Roe et al., 2016), greater than in professional soccer (Ekstrand et al., 2023). According to a recent meta-analysis of biomechanical studies in sprint mechanics, the hamstring muscle is particularly vulnerable to injury at the terminal swing phase, when the hamstrings reach their maximum length and contract eccentrically right before heel striking (Danielsson et al., 2020).

Greater high-speed running volume, rapid changes in high-speed running volume, and decreased eccentric hamstring strength are proposed risk factors for hamstring injury (Green et al., 2020). Research in Australian rules football found that players with eccentric hamstring strength below 256N were 2.7 times more likely to sustain a hamstring injury, while elite soccer players with eccentric hamstring strength below 337 had a 4.4 times increased risk of hamstring injury (Opar et al., 2015; Timmins et al., 2016). However, a recent meta-analysis concluded that absolute eccentric hamstring strength measured at preseason was not a risk factor for subsequent hamstring injury (SMD = − 0.22, p =0.02, 95% CI = − 0.50 to 0.05) (Opar et al., 2021). Although eccentric hamstring strength measured at pre-season as a once-off test was not associated with a hamstring injury in Gaelic football previously (Roe et al., 2020), more regular monitoring is needed to identify risk factors such as eccentric strength. It is crucial to consider that strength might alter across the preseason and during the regular season (Opar et al., 2015). Players' inherent risk factors and susceptibility to injury could change as a result of a single exposure to a possible inciting event. As a result, the player may be exposed to the same or different extrinsic risk factors and have a different propensity to injury (Meeuwisse et al., 2007). Therefore, it is critical to regularly monitor risk factors such as eccentric hamstring strength.

Running exposure, particularly high-speed running volume over the previous 7-14 days, is associated with hamstring injuries in Australian rules football (Duhig et al., 2016; Ruddy et al., 2018). The acute workload defined as the distance covered the week before an injury, had the most significant influence on injury risk (OR=6.44) (Duhig et al., 2016). Hamstring injury risk increased over 3-fold when the preceding weekly distance covered above 24 km/hour was >653 m and the absolute week-to-week change in distance covered above 24 km/hour was >218 m (Ruddy et al., 2018). No previous research has investigated the association between high-speed running volumes and hamstring injuries. However, two studies have looked at training load (in arbitrary units [AU] measured as session-RPE multiplied by the duration of the session in mins) and injury in elite Gaelic footballers (Malone et al., 2017a; 2017b). Gaelic footballers had an increased risk of general injury when their weekly total training load was greater than 2700 arbitrary units late in the season (AU) (OR=8.3) (Malone et al., 2017b). Similarly, the risk of injury was significant when the Gaelic footballer had an absolute change in training load from the previous week between ≥ 250 AU to ≤ 550 AU (OR=6.5). Players with a lower chronic training load (rolling average 4-weekly workload) that completed between 10-15 maximal velocity exposures had a greater risk of injury (OR=1.4) than those with a higher chronic training load (Malone et al., 2017a). Gaelic footballers exerting modest chronic training loads (<4750 AU) who completed a maximal velocity distance of 90-120m were at a substantially greater risk of injury than the reference group of footballers who covered <60m at maximal velocity (OR = 3.2) (Malone et al., 2017a). Although these studies were not specific to hamstring injuries, the results show that changes in training load, particularly if their chronic training load was low, was a risk factor for injury in Gaelic footballers. Although high-speed running is the principal mechanism of hamstring injuries (Opar et al., 2012), there has been no research in Gaelic games that has looked at training load, specifically high-speed running volume and its association with hamstring injuries.

Reduced ankle dorsiflexion has been found to be associated with a hamstring injury. However, the exact reasons for this are unknown, but ankle dorsiflexion mobility is essential for running (Bohannon et al., 1989). Reduced ankle mobility while running alters the foot's touchdown position, resulting in less horizontal force generation (Bezodis et al., 2015), potentially forcing the hamstring muscles to compensate and to work harder to overcome the loss of force (van Dyk et al., 2018), which may result in injury. AFL players with a knee to wall <10cm had an increased relative risk (2.32) of hamstring injury compared to players ≥14cm (Gabbe, 2005). Similarly, in professional soccer, players with an increased dorsiflexion angle of motion had a decreased risk of hamstring injury (OR=.89) (van Dyk et al., 2018). Ankle dorsiflexion range of motion has not previously been investigated for an association with a hamstring injury in Gaelic football players.

Physical performance might be affected for up to several days by exercise-induced muscle damage and fatigue (Clarkson et al., 1992). Increased injury risk is also linked to cumulative fatigue across training and matches, particularly when total training loads or intensities are rapidly increased (Gabbett, 2016). A key component of player welfare systems is the monitoring of player workload and response to workload in the form of subjective and objective assessments of fatigue (Thorpe et al., 2017). In high-performance sporting environments, the countermovement jump (CMJ) test has been established as the "gold standard" test for detecting neuromuscular fatigue (Garrett et al., 2019). Fatigue can be classified as a decreased capacity to provide the necessary performance output, which restricts both physical and mental abilities (Alba-Jiménez et al., 2022). In fatigue conditions the hamstrings have decreased muscle activation of the bicep femoris (Rimmer et al., 2020), movement compensation (Samaan et al., 2015), decreased horizontal force production (Edouard et al., 2017) and decreased eccentric hamstring strength (Edouard et al., 2017) which increase the risk of hamstring injuries in Gaelic footballers. However, there is no research on this association among Gaelic footballers.

A player's risks in a real-world athletic setting may fluctuate regularly and are dynamic (Meeuwisse et al., 2007). Therefore, in order to apply injury risk management techniques, multiple strength, running volumes and range of motion assessments throughout the season may offer a more reliable indicator of a player's risk of injury (Bourne et al., 2015). Therefore, the primary aim of this study was to investigate if high-speed running volume, eccentric hamstring strength, ankle dorsiflexion range of motion and CMJ was different for the injured players and uninjured players on the week of an injury. Furthermore, we aimed to investigate if eccentric hamstring strength, ankle dorsiflexion range of motion and CMJ scores differed from preseason, midseason and end season. Finally, the study investigated if preseason screening could predict Gaelic games players that sustained a hamstring injury.

4.2 Methods

An observational prospective cohort study was conducted over a period of 9 weeks of the club championship and inter-county preseason. Ethical approval was granted by Dublin City University's Ethics Committee (DCUREC/2019/206), and written signed informed consent was provided prior to the beginning of the study.

4.2.1 Participants

The primary investigator contacted the teams medical and strength and conditioning departments and gained permission from management to conduct the research. Due to the COVID-19 pandemic the team were recruited by convenience sample due to local restrictions at the time. Thirty-eight elite male Gaelic footballers (age = 24.6±3.5 years, height = 183.2±5.9 cm, mass = 82.2±6.0 kg, $VOmax^2$ = 57.3±2.2) from one elite senior Gaelic football team. Each player completed a questionnaire which included their lower limb injury history within the preceding 12 months as well as player demographics such as age and position was recorded. Participants were excluded from the study if they had a current lower limb injury.

4.2.2 Instrumentation

Height was measured in cm, weight in kg, body fat percentage, and lean tissue mass using a Dexa scan.

4.2.2.1 Running Volume using GPS

Running volume was objectively measured using VX Sport 4 Hz GPS units (VX Sport; Visuallex Sport, New Zealand, Firmware: V1.60 28). VX Sport GPS units are valid, accurate, and reliable during intermittent activity (Malone et al., 2014; Coutts and Duffield, 2010). Each player was given their own individual GPS unit for use over the nine weeks, which was placed in a specifically designed VX Sport vest so that the GPS unit was worn on the back between the scapulae for all matches and training sessions. The VX software was used to download GPS data after each session (VX Sport View, New Zealand V1.60 28). All the GPS variables that were collected are shown in Table 4.1. High-speed running was defined as greater than 17 km/h as previously used in Gaelic football (McGahan et al., 2020; Malone et al., 2021).

4.2.2.2 Knee-to-Wall test

The knee-to-wall test (Figure 4.1) was used as previously described (Bennell et al., 1998; van Dyk et al., 2018). A tape measure was fixed along the floor with the 0 cm point at the junction of the floor and wall. The player positioned their foot beside the tape so that their heel and big toe were aligned beside the tape measure. The player was instructed to lunge forward until their knee touched the wall. Once the player's heel raised or the knee could not touch the wall, the maximum distance from the great toe to the wall was recorded in cm. The test was conducted three times, and the maximum score was recorded.

Figure 4. 1. The Knee-to-Wall test.

4.2.2.3 Countermovement Jump

The CMJ (Figure 4.2) was performed as previously described (Barker et al., 2018). The protocol was performed without an arm swing which demands the athlete to keep their hands on their hips, isolating the production of force from the lower extremities by reducing the effect of arm swing (Heishman et al., 2019). Jump technique was also demonstrated to each individual prior to testing. Each trial began with the participants standing still with each foot on a FD4000 dual force plate (Force Decks, Vald Performance, Newstead, QLS, AUS). Following the initiation of the countermovement, participants attempted to jump vertically as high as possible. Players were instructed to "lower themselves as quickly as possible, jump as high as possible, and return to standing after landing while maintaining their hands on their hips". Countermovement depth was not controlled. Players completed three max effort jumps and had 15 seconds rest between each rep. The best performance from each jump was recorded. All data were collected and analysed using the dual force plates sampling at 1000Hz and the force decks software (Force decks, Vald Performance, Newstead, QLS, AUS). The purpose of this test was to measure jump height and the modified reactive strength index (RSImod) and was calculated as jump height divided by time to take off (Ebben and Petushek, 2010).

Figure 4. 2. Countermovement Jump.

4.2.2.4 Nordic Hamstring test

The Nordic hamstring test (Figure 4.3) was performed as previously described (Opar et al., 2013). The players were positioned in a kneeling position on the hamstring solo elite (NJ Doherty Solutions, Kilkenny, Ireland), cushioned surface with their ankles locked beneath the load cells, just superior to the medial and lateral malleoli. The players were instructed to lower their torso slowly toward the ground by only extending at the knee joint until they could no longer sustain the eccentric hamstring contraction and land on their palms on the floor. During the repetitions, the players were advised to maintain a straight line from the shoulder to the knee by limiting hip flexion and lumbar lordosis to the best of their ability. There was no specified minimum range of motion, and repetitions were discarded if participants demonstrated a loss of control on descent or significant hip movement during the repetition. After each repetition, the peak force (N) generated for the left and right limbs was recorded through wireless data acquisition from the Hamstring Solo Elite device load cells and the Hamstring Solo Elite app (version 4.2, ND Sports Performance), which also allowed for the calculation of relative force. The players performed three repetitions, and the maximum score was recorded. The Hamstring Solo Elite device is a reliable and valid device that measures eccentric hamstring strength objectively (Lodge et al., 2020).

Figure 4. 3. Nordic Hamstring test.

4.2.2.5 The Yo-Yo test

The Yo-Yo Intermittent Recovery test level 2 (Yo-Yo) (Figure 4.4) was performed as previously described (Bangsbo et al., 2006). The Yo-Yo consists of 2 x 20-m shuttle runs at increasing speeds, with a 10-second active recovery between each run (controlled by audio signals from a compact disc player). A verbal warning was given for failing to finish a shuttle, with participants excluded from the test after a second consecutive failure. At the final completed shuttle, the total distance and associated maximum speed were recorded. The purpose of this test was to evaluate an player's ability to repeatedly complete short, high-intensity running efforts.

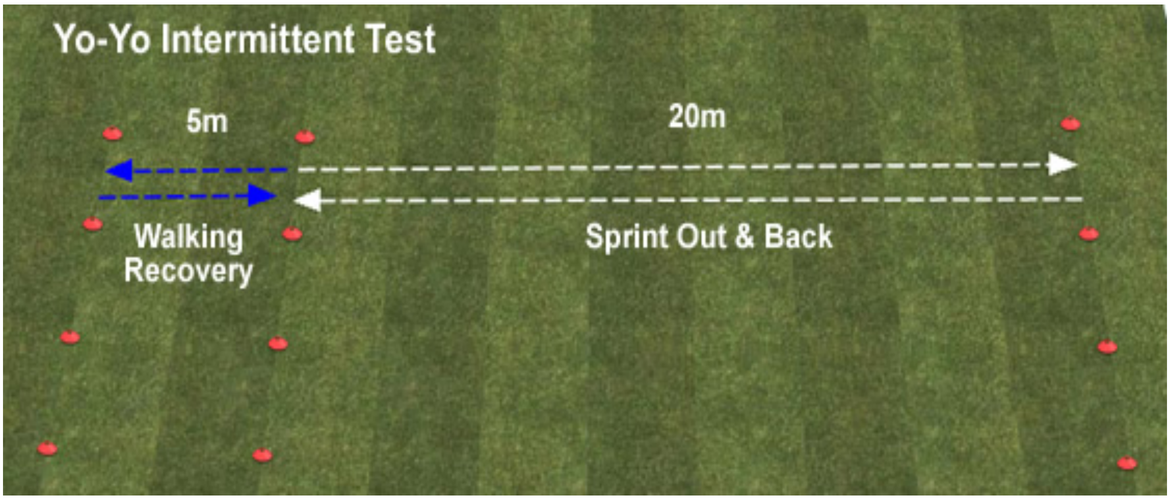

Figure 4. 4. Yo-Yo Intermittent Recovery test.

4.2.3 Procedures

All players attended a preseason screening. Testing was conducted in a station format, and players rotated between the stations during the tests. Four testers (one Certified Athletic Therapist and three strength and conditioning coaches, of which two held a PhD) remained at the same station and completed the same tests throughout. The tester read the test instructions to the player and demonstrated the test at each station. Four tests were completed in the same order (Figure 4.5), including the knee-to-wall test, the countermovement jump, the Nordic Hamstring Exercise test, and the Yo-Yo test. The players were asked to state their dominant leg (preferred kicking leg) (Witvrouw et al., 2003). Players received one trial attempt for familiarisation followed by 3 max effort attempts in which the best score was recorded. Before testing, the players completed a standardised dynamic warm-up, including 5 single leg RDLs, 5 body weight squats, 5 lunges, 5 single leg hamstring bridges, and 3 countermovement jumps at 50%, 70% and 90%.

Over the course of the 9-week club period, players were monitored on a weekly basis. Players completed on average 2.8 field sessions per week as well as one collective gym session and one individual gym session over the course of the study. During the field training sessions and matches, all players wore GPS trackers to track their running speeds and volume. Similarly, with a minimum of 48 hours post-match, knee-to-wall, CMJ and eccentric hamstring strength were also monitored as described previously prior to training.

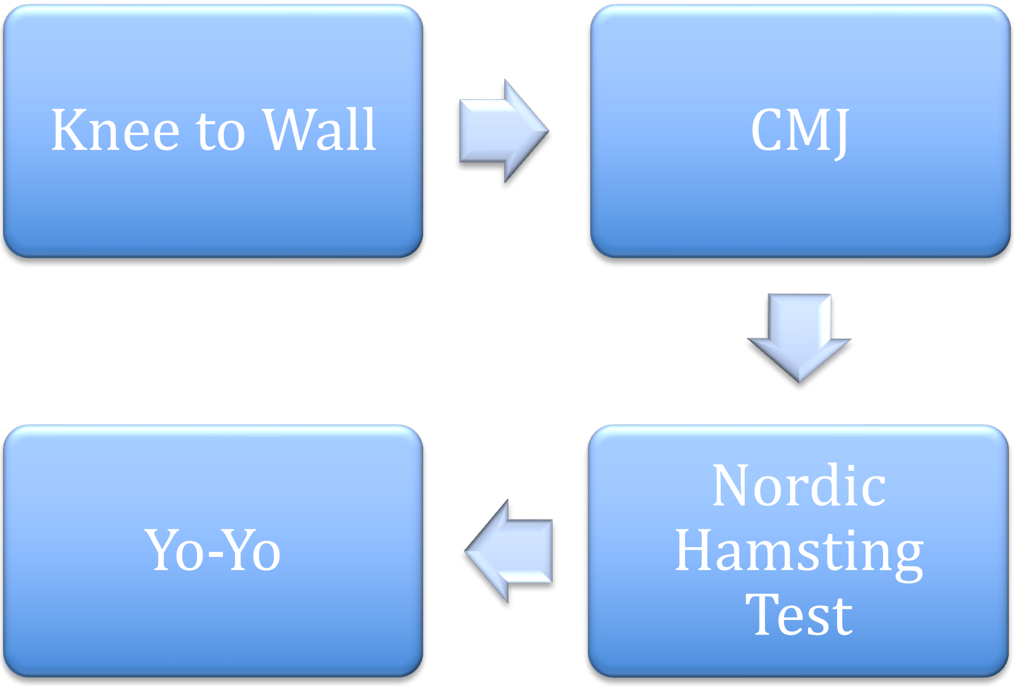

Figure 4. 5. Sequence of testing procedure.

4.2.4 Reporting of Prospective Hamstring Injuries

All hamstring strains were prospectively captured over the course of the 9 weeks. All injuries were diagnosed by the team doctor or chartered physiotherapist. Only injuries that prevented a player from taking a full part in all training and match play activities typically planned for that day, where the injury has been there for a period >24 hours from midnight at the end of the day that the injury was sustained, was recorded for this study (Murphy et al., 2012).

4.2.5 Statistical Analysis

Data was transferred and stored on Excel (2020, version 16.34; Microsoft Corporation, Redmond, WA, USA) and checked for missing information. The data was then transferred and analysed using SPSS (2021, version 27.0; IBM Corp, Armonk, NY). For each individual player, the data from each session was then summed across a week, which was defined as a seven-day period beginning Monday and ending Sunday. All the GPS variables that were collected are shown in Table 4.1.

Table 4. 1. GPS variables measured in this study, their units, and zones

Variable	**Unit**	**Zone**
Total Distance	m	-
High-Speed Running Distance	m	>17km/h
Max Speed	Km/h	-
High Intensity Sprints	n	-
Sprint Distance	m	>22 km/h
Sprints Zone 4	N	>17km/h
Sprints Zone 5	n	>22 km/h

m: meters; km/h: kilometres per hour; n: number of efforts.

4.2.5.1 Hamstring Injuries

Incidence proportion was calculated by number of injured players during a season divided by the number of players at risk during the season (van Mechelen et al., 1992). Injury rates were calculated by the number of injuries divided by the total player exposure hours multiplied by 1000 and were expressed as injuries per 1000 hours (O'Connor et al., 2016). Injury burden was calculated as the total days lost divided by the total exposure hours multiplied by 1000 and is expressed as days absent per 1000 player hours.

4.2.5.2 Injured and Uninjured players

An uninjured matched case with the same position, level and age was identified from the uninjured cohort. Their load and performance tests from the same week were compared to the injured player using a matched-pairs t test. Statistical significance was set at 0.05. Effect sizes were calculated using eta squared (η2) and classified as follows: small (.01), medium (.06) and large (.14) (Cohen, 2013).

4.2.5.3 Injured Players

GPS data for injured players was compared over the course of the season. For each hamstring injury, the mean player load was calculated in the 1 week leading up to injury (injury block) and in the one week preceding the injury block (preinjury block) (Li et al., 2020). One week was chosen as it was previously found that the volume in the week preceding an injury had the greatest effect on hamstring injury (Duhig et al., 2016). The mean weekly player load was also calculated from the start of preseason to the point of injury. One-way ANOVAs were used to determine differences in GPS variables and performance tests between the injury block, preinjury block, and the season average for injured players. Post hoc analysis was conducted to determine differences in player load between individual blocks. A 0.05 level of statistical significance was used. The effect size was also calculated using eta squared ($\eta 2$) and was classified as small (.01), medium (.06) and large (.14).

4.2.5.4 Preseason Predictors

Univariate analyses were completed to examine the association of variables at pre-season and the future risk of sustaining a hamstring injury. Each of the following variables were analysed: Body Mass Index (BMI), Body fat percentage, lean tissue mass, V02max which was measured using Yo-Yo, a hamstring injury in 2019, other injuries to the lower limb in 2019, age, eccentric knee flexor strength on both left and right limbs, the percentage difference between dominant and non-dominant limb, knee to wall and jump height. Odds ratios (OR), 95% confidence intervals and p-values were reported. A multivariate backwards-step regression model was then used. Multicollinearity was checked using the variance inflation factor. Only variables that produced a p-value of less than 0.20 in the univariate analysis were included in the backward stepwise regression model (Van Middelkoop et al., 2008). A p-value <0.10 was used as a cut-off level for eliminating non-significant predictors at each step. An alpha level of 0.05 for the statistical significance of the overall model was used. The sensitivity and specificity of the overall multivariate model was examined along with the odds ratio (OR) and 95% Confidence Intervals (95% CI) of each individual variable in the models.

4.2.5.5 Performance across the season

A one-way ANOVA was used to determine differences in performance tests across 3-time points across the season (preseason, midseason and end season). Statistical significance was set at 0.05. Effect sizes were calculated using eta squared ($\eta 2$) and classified as small (.01), medium (.06) and large (.14).

4.3 Results

4.3.1 Hamstring Injuries

A total of 9 hamstring injuries occurred during the study period. The hamstring injury incidence proportion was 24%. Hamstring injuries were the most frequently occurring injury during this period (36%), with a high injury rate (12.48 injuries/1000 hours). The mean time lost due to hamstring injury was 16.8±9.5 days, with an injury burden of 209.4 days absent per 1000 hours of exposure.

4.3.2 Season means for all variables

The mean weekly total distance, high-speed running distance and sprint distance were 12557.8 ± 2245.1m, 2102.3 ± 622.1m and 674.2 ± 234.5m respectively. Players completed 99.2 ± 27.7 high intensity sprints each week. The mean eccentric knee flexor strength was 335.8 ± 88.4N and 352. 4± 85.9N, non-dominant and dominant respectively. Gaelic football players mean jump height on the CMJ was 39.5 ± 4.5cm. All other variables are reported in Table 4.2.

Table 4. 2. Season mean for GPS variables and physical test for total, injured and uninjured players.

	Total Mean ± SD	**Injured Mean ± SD**	**Non-Injured Mean ± SD**	***p-value***	**Effect size (η2)**
Total Distance (m)	12557.8 ± 2245.1	12890.5 ± 2376.9	12568.8 ± 2074.7	.804	.01
High Speed Running Distance (m)	2102.7 ± 622.1	2114.1 ± 589.1	2157.3 ± 636.7	.322	.03
Max Speed (km/h)	30.0 ± 1.3	29.9 ± 1.1	30.1 ± 1.1	.787	.01
High Intensity Sprints (n)	99.2 ± 27.7	102.4 ± 28.6	98.7 ± 27.3	.846	.01
Sprint Distance (m)	674 .2± 234.5	711.6 ± 268.3	688.5 ± 225.6	.322	.03
Sprints Zone 4 (n)	63.9 ± 18.2	65.8 ± 20.4	63.3 ± 17.8	.710	.01
Sprints Zone 5 (n)	34.1 ± 10.4	34.2 ± 10.2	34.2 ± 10.2	.683	.01
Eccentric Knee Flexor strength non-dominant (N)	335.8 ± 88.4	342.0 ± 83.0	335.2 ± 91.3	.932	.01
Eccentric Knee Flexor strength dominant (N)	352.4 ± 85.9	358.2 ± 77.0	350.6 ± 89.7	.850	.01
Eccentric strength non-dominant relative to body weight (N/kg)	4.01 ± 1.04	39.6 ± 3.8	4.07 ± 1.09	.494	.02
Eccentric strength dominant relative to body weight (N/kg)	4.26 ± 1.04	39.8 ± 4.0	4.32 ± 1.12	.497	.03
Percentage difference dominant limb to non-dominant limb (%)	11.4 ± 7.3	10.4 ± 6.2	11.8 ± 7.7	.718	.01
Knee to wall Left (cm)	12.5 ± 2.7	12.3 ± 3.0	12.5 ± 2.7	.837	.01
Knee to wall Right (cm)	12.3 ± 2.9	11.3 ± 2.4	12.6 ± 3.0	.197	.07
Jump height (cm)	39.5 ± 4.5	41.1 ± 5.0	39.0 ± 4.2	.272	.04
RSImod (m/sec)	.51 ± .08	.51 ± .09	.50 ± .08	.744	.01

SD: standard deviation; RSImod: modified reactive strength index; m: meters; km/h: kilometres per hour; n: number of efforts; N: newtons; N/kg: newtons per kilogram; %: percentage; cm: centimetres; m/sec: meters per second; p: p value significant at $p<0.05$.

4.3.3 Injured and Uninjured Players

There was no significant difference between injured and uninjured players' season mean for any of the running and performance metrics (p=>.05) (Table 4.2). In addition, no significant difference was found between injured and uninjured players' for any of the performance tests, total distance, max speed and number of sprints in speed zone 4, on the week of an injury (Table 4.3) (p>.05). Table 4.3 details the mean, standard deviation and p-value for all variables tested between injured players and their matched controls. Injured players displayed significantly greater high-speed running distance (p=.009, $\eta 2$= .63), high-intensity sprint efforts (p=.021, $\eta 2$=.54), sprint distance (p=.009, $\eta 2$=.63) and number of sprints in speed zone 5 (p=.003, $\eta 2$=.72) than their uninjured counterparts.

Table 4. 3. Mean, standard deviation and p-value for all variables for injured and uninjured matched cases.

	Injured	**Matched Control**	***p-value***	**Effect size (η2)**
	Mean ± SD	**Mean ± SD**		
Total Distance (m)	15366.7 ± 3491.8	12657.7 ± 3856.2	.162	.22
High Speed Running Distance (m)	2646.4 ± 498.2	1976.8 ± 731.5	.009*	.63
Max Speed km/h	31.2 ±1.6	30.2 ± 1.6	.143	.25
High Intensity Sprints (n)	132.1 ± 31.4	95.7 ± 31.8	.021*	.54
Sprint Distance (m)	952.8 ± 287.3	706.9 ± 334.9	.009*	.63
Sprints Zone 4 (n)	82.2 ± 25.2	65.3 ± 22.5	.115	.24
Sprints Zone 5 (n)	48.6 ± 10.5	34.3 ± 12.0	.003*	.72
Eccentric Knee Flexor strength non-dominant (N)	324.3 ± 60.9	371.9 ± 117.9	.319	.20
Eccentric Knee Flexor strength dominant (N)	358.7 ±76.7	350.7 ±102.3	.900	.01
Eccentric strength non-dominant relative to body weight (N/kg)	3.8 ± .8	4.5 ± 1.9	.354	.28
Eccentric strength dominant relative to body weight (N/kg)	3.9 ± .9	4.4 ± 1.7	.685	.06
Percentage difference dominant limb to non-dominant limb (%)	16.5 ± 4.4	9.5 ± 7.0	.124	.41
Knee to wall Left (cm)	13.0 ± 2.4	11.3 ± 2.5	.233	.27
Knee to wall Right (cm)	12.2 ±1.9	11.2 ± 2.6	.391	.15
Jump height (cm)	40.4 ± 6.1	39.3 ± 2.9	.771	.03
RSImod (m/sec)	.49 ± .09	.48 ± .03	.874	.01

SD: standard deviation; RSImod: modified reactive strength index; *: Statistically significant; η2, effect size; m: meters; km/h: kilometres per hour; n: number of efforts; N: newtons; N/kg: newtons per kilogram; %: percentage; cm: centimetres; m/sec: meters per second; p: p value significant at $p<0.05$

4.3.4 Preseason Predictors

Table 4.4. displays the univariate regression analysis between preseason performance measure and hamstring injuries. Three of the 15 variables (age, hamstring injury in the previous 12 months and jump height) had a $p<0.20$ and were then imputed into the multiple logistic regression model.

The final multivariable logistic model after backward elimination is represented in Table 4.5. The model contained two independent variables (hamstring injury in the previous season and jump height). The full model containing all predictors was statistically significant, $\chi 2$ (2, N = 28) = 10.67, p=.010, indicating that the model could distinguish between respondents who had and did not have a hamstring injury. The model explained between 28.0% (Cox and Snell R square) and 41.4% (Nagelkerke R squared) of the variance in hamstring injury and correctly classified 89.3% of cases. A hamstring injury in the previous year (OR 10.60; CI 1.05–107.41) and increased jump height during the CMJ (OR 1.40; CI 1.01–1.93) were associated with the occurrence of a hamstring injury.

Table 4. 4 Univariate analysis of preseason predictor variables.

Variables	**OR**	**95%CI**	***p*-value**
BMI	1.29	.646-2.576	.471
Body Fat	1.134	.841-1.529	.410
Lean Tissue Mass	1.024	.868-1.209	.776
VO2max	.984	.616-1.571	.947
HSI 2019	4.792	.975-23.555	.054*
Other Injury 2019	.352	0.62-1.991	.237
Age	1.202	.963-1.501	.104*
Eccentric Knee Flexor strength non-dominant (N)	1.005	.996-1.014	.323
Eccentric Knee Flexor strength dominant (N)	1.005	.996-1.015	.260
Eccentric strength non-dominant relative to body weight (N/kg)	1.123	.496-2.540	.781
Eccentric strength dominant relative to body weight (N/kg)	1.128	.512-2.484	.765
Percentage difference dominant limb to non-dominant limb (%)	.951	.852-1.062	.373
Knee to wall Left (cm)	.954	.720-1.265	.744
Knee to wall Right (cm)	.887	.685-1.148	.361
Jump height (cm)	1.276	.987-1.651	.063*

OR: odds ratio; CI: confidence interval; *:included in multivariate analysis; N: newtons; N/kg: newtons per kilogram; %: percentage; cm: centimetres; p: p value significant at $p<0.05$.

Table 4. 5 Multivariate analysis final model of preseason predictor variables.

Variables	**OR**	**95%CI**	***p*-value**
HSI 2019	10.603	1.047-107.414	.046*
Jump Height	1.395	1.006-1.934	.046*

OR: odds ratio; CI: confidence interval; *: statistically significant; p: p value significant at $p<0.05$.

4.3.5 Performance across the season

There was no significant difference between the season mean for injured and uninjured players for all physical tests ($p>.05$) (Table 4.2). In addition, no significant difference between pre-season physical test, in-season physical test and end-of-season performance test was observed ($p>.05$) (Table 4.6).

Table 4. 6. The different physical test mean difference and p values for preseason, mid-season and end season.

	Preseason	**Mid-season**	**End season**	***p-value***	**Effect size (η2)**
	Mean ± SD	**Mean ± SD**	**Mean ± SD**		
Eccentric Knee Flexor strength non-dominant (N)	328.6 ± 91.9	326.2 ± 91.8	343.1 ± 90.7	.692	.01
Eccentric Knee Flexor strength dominant (N)	343.8 ± 90.7	347.1 ± 87.5	359.9 ± 89.1	.703	.01
Eccentric strength non-dominant relative to body weight (N/kg)	3.9 ± 1.1	3.9 ± 1.1	4.1 ±1.1	.762	.01
Eccentric strength dominant relative to body weight (N/kg)	4.2 ± 1.1	4.2 ± 1.1	4.3 ± 1.1	.846	.01
Percentage difference dominant limb to non-dominant limb (%)	11.5 ± 8.8	13.1 ± 7.5	10.7 ± 7.9	.462	.02
Knee to wall Left (cm)	12.7 ± 2.8	12.4 ± 2.9	12.4 ± 2.8	.879	.01
Knee to wall Right (cm)	12.1 ± 3.1	12.2 ±3.0	12.3 ± 2.9	.977	.01
Jump height (cm)	40.5 ± 4.2	39.4 ± 4.4	39.9 ± 4.4	.615	.01
RSImod (m/sec)	.51 ± .08	.50 ± .09	.51 ± .08	.814	.01

SD: standard deviation; RSImod: modified reactive strength index; η2: effect size; N: newtons; N/kg: newtons per kilogram; %: percentage; cm: centimetres; m/sec: metres per second; p: p value significant at $p<0.05$.

4.4 Discussion

The purpose of the current study was to investigate if high-speed running exposure and performance tests measured weekly throughout the season were different for those that sustained a hamstring injury and those that did not in elite male Gaelic footballers. Similarly, the study investigated if Gaelic footballers' performance tests differ at different stages across the season. The key findings from this study were that injured players completed significantly greater distances at speeds greater than 17km/h than their uninjured matched counterparts on the week of the injury. These results show that hamstring strain injury risk increases with substantially higher high-speed running volume. From an injury prevention standpoint, training loads, particularly distances at speeds greater than 17km/h should be monitored on an individual basis weekly for elite Gaelic footballers and gradual increases are recommended. However, when interpreting and adapting the current findings to the high-performance sports context, caution should be taken from a training performance perspective. There must be a careful balance between limiting training loads to prevent injuries and increasing loads to physically prepare players for competition (Gabbett and Ullah, 2012), as Gaelic football has been described as an intermittent high-intensity sport in which players need high levels of physical conditioning to compete (Brown and Waller, 2014). However, the performance tests performed during the season in this study did not differ for uninjured matched controls on the week of the injury.

4.4.1 Running Exposure

Although methodological differences exist, greater high-speed running distance in AFL the week preceding an injury had the largest impact on the hamstring injury risk (OR=6.44) (Duhig et al., 2016). This implies that abrupt changes or spikes occurred in workload on the week of injury are linked to a higher risk of hamstring injuries. However, players with higher chronic training loads can tolerate greater exposures to high-speed running with a reduced risk of injury compared with players with a lower chronic training load (Malone et al., 2017a). Similarly, players who achieved 95% or more of their max speed each week have a decreased risk of injury than those who produced lower relative maximum speeds (OR=0.12) (Malone et al., 2017a). Additionally, they found that individuals with moderate exposures to maximum velocity (>6–10) had a decreased risk of injury compared with players with lower (<5) exposures (OR=0.24) (Malone et al., 2017b). Therefore, it is essential that Gaelic footballers are monitored and maintain relatively stable weekly high-speed running volumes and are exposed to maximum velocities regularly and avoid rapid spikes.

Previously it was found in the AFL players that relative week-to-week change in speed of >24km/h greater than 2.0 had an increased risk of hamstring injury (RR=3.6) (Ruddy et al., 2018). Unfortunately, a direct comparison cannot be made between the studies due to methodological differences. Nonetheless, both studies suggest that an elevated high-speed running exposure or a rapid spike increases the risk of a hamstring injury. Absolute week-to-week change in distance covered above 24km/h >218m had an increased risk of hamstring injury in AFL (RR=3.3) (Ruddy et al., 2018). Previous research demonstrates the futility of assuming transferability across sports for modifiable risk factor cut points and emphasises the value of replicating studies across several cohorts for variables linked to potential hamstring injury (Lee Dow et al., 2021). In order to reduce the likelihood of hamstring injuries while maintaining the required chronic load for performance, the current findings offer some support to avoid large and rapid spikes in workloads by monitoring in particular players' high-speed running on a weekly basis.

4.4.2 Performance tests

No performance test significantly differed between injured and uninjured players. Only a single study has investigated the Nordic hamstring test and its association with hamstring injury across various time points (Opar et al., 2022). Like the current study, absolute eccentric knee flexor strength and eccentric knee flexor strength relative to body mass measured at various time points had no association with a hamstring injury. However, when evaluated at numerous time periods, a more than 9% limb imbalance was linked to a future hamstring injury (RR=1.81) (Opar et al., 2022). Opar et al. (2022) concluded that more regular screening of eccentric hamstring strength did not improve the prediction of hamstring injuries. However, it must be noted that testing was only completed on three occasions over 10 months. Although the current study monitored the performance tests weekly over nine weeks, future research should focus on more monitoring weekly for a longer duration and with greater participant numbers.

4.4.3 Preseason testing

4.4.3.1 Non-modifiable Risk Factors

Previous history of a hamstring injury in the last 12 months was a risk factor for hamstring injuries in the current year in this study (OR=4.8). This is in line with a recent meta-analysis which found that previous hamstring injury had a risk ratio of 2.7 for subsequent hamstring and was even more enhanced for previous hamstring injuries within the same season (RR=4.8) (Green et al., 2020). Specifically, in elite Gaelic football, 44% of players that sustained a hamstring injury received a subsequent hamstring injury, with a risk ratio of 3.3 (Roe et al., 2016). Previously, other previous injuries were also a risk factor for hamstring injury (Green et al., 2020). However, this was not the case in this current study. The most significant predictor of future risk of musculoskeletal injury is unquestionably a history of prior injuries (Bahr, 2016). Although the underlying reasons for previous hamstring injuries and their link to subsequent hamstring injuries are not fully understood, structural maladaptations such as shortening of the biceps femoris fascicle (Timmins et al., 2016), decreased flexibility (Fyfe et al., 2013), muscle atrophy (Fyfe et al., 2013; Sanfilippo et al., 2013), and the development of inelastic scar tissue (Fyfe et al., 2013; Silder et al., 2008) occur due to injury which may reduce the hamstrings' ability to resist significant stress and strain, increasing the possibility of recurrence (Green et al., 2020). Although a previous history of hamstring injury is a non-modifiable risk factor and cannot be altered, it is essential to identify those who are most likely to sustain injuries, allowing injury prevention efforts to be concentrated on those who most need them.

Age was not significantly associated with a hamstring injury in this current study. However, in contrast, previously in elite Gaelic footballers, younger players (18-20 years) and older players (>30 years) had an injury rate ratio (IRR) of 2.3, while middle-aged players were at decreased risk of hamstring injury (Roe et al., 2016). Increased age is well-established as being associated with a hamstring injury (Green et al., 2020). However, in the current study there was a short timeframe and this may explain why age was not associated with a hamstring injury. Therefore future research should be conducted over a larger timeframe.

4.4.3.2 Modifiable Risk Factors

Absolute eccentric hamstring strength measured at preseason was not a risk factor for a subsequent hamstring injury. This is in agreement with previous work in Gaelic football (Roe et al., 2020), AFL (Smith et al., 2021; Ruddy et al., 2018), soccer (van Dyk et al., 2017), Rugby (Bourne et al., 2015) and American collegiate players (Wille et al., 2022). However, two studies found an association between absolute eccentric hamstring strength and a hamstring injury in AFL (Opar et al., 2015) and soccer (Timmins et al., 2016). Soccer players with an absolute eccentric strength below 337N and AFL players below 256N were 4.4 and 2.7 times more likely to suffer a hamstring injury, respectively. However, in the current study, injured players had a mean absolute eccentric strength greater than both values. The stronger players in the current study may be due to training regimes that included Nordic strength training. Two meta-analyses and systematic reviews have found that including the Nordic curl exercise as part of training significantly increases eccentric hamstring strength when measured using the Nordic hamstring test (Bautista et al., 2021; Medeiros et al., 2021). One study in collegiate Gaelic footballers found that a four-week programme of the Nordic curl exercise improved eccentric peal torque by 19.8% and 15.5% in the dominant and non-dominant limbs, respectively (Whyte et al., 2021). This may explain why the players in this study had greater scores than the previous studies that identified absolute peak eccentric hamstring strength as a risk factor for injury. Similarly, eccentric hamstring strength relative to body mass measured at preseason was not associated with hamstring injuries. Absolute strength is considered intrinsically problematic since it fails to consider variations in body mass and/or lever arms across individuals (Buchheit et al., 2016). However, the meta-analysis found that relative eccentric hamstring strength was similarly not a risk factor for hamstring injury when body mass was considered (SMD = 0.23) (Opar et al., 2021).

There was no association between-limb imbalance and hamstring injury in the current study. Large imbalances or asymmetries may result in less efficient muscle activity or biomechanics (Heiderscheit et al., 2010). However, similar to our study, 4 out of 5 studies that investigate between-limb imbalance as a risk factor for hamstring injury using the Nordic hamstring exercise test found no significant results (Roe et al., 2020; van Dyk et al., 2017; Opar et al., 2015; Timmins et al., 2016). Therefore, our study supports the view of the current literature that using the Nordic hamstring test in pre-season offers minimal value in injury prediction (Opar et al., 2021) but must be considered with caution as the players in the present study had increased eccentric strength compared to the two studies that showed decreased strength to be a risk factor for hamstring injuries (Opar et al., 2015; Timmins et al., 2016). However, it may have some value in obtaining baseline scores which may be used as part of the rehabilitation process. Alternatively, the Nordic hamstring test could be used to determine if Nordic hamstring curl interventions are having the desired effect.

Increased jump height measured using the CMJ was associated with a hamstring injury. This suggests that explosive power may be associated with a hamstring injury. Previously in elite soccer players, for every 1cm increase in jump height, hamstring injury risk increased by 1.47 times (Henderson et al., 2010). Practically speaking, these findings pose a conundrum because explosive strength is a recognised prerequisite for effective performance in elite-level sports. Yet, power gains also may increase the risk of hamstring injuries in both soccer and Gaelic football (Henderson et al., 2010). Alternatively, the quadricep muscles are more active than the hamstrings during the CMJ (Cerrah et al., 2014), and increased quadriceps strength compared to hamstring strength could lead to significant asymmetries and potential injury. Therefore, the aim of coaches should be for uniform increases in strength across all muscle groups. However, further research is needed as both studies had limited participant numbers.

Ankle dorsiflexion range of motion measured using the knee-to-wall test was not associated with a hamstring injury in this study. Two previous studies have found reduced dorsiflexion range of motion as measured with the knee-to-wall test in soccer (van Dyk et al., 2018) and AFL (Gabbe et al., 2006) players were associated with a hamstring injury. Van Dyk et al. (2018) found that injured soccer players had a knee-to-wall of 9.8cm compared with 11.2cm in uninjured players. Similarly, Gabbe et al. (2006) found that <10cm had a 2.3-fold increase in hamstring risk in AFL players. In the current study injured players had a knee-to-wall of 12.3cm and 11.3cm on the left and right side respectively which is greater than previously reported. However, van Dyk et al. (2018) had 18 soccer teams included in the study, and Gabbe et al. (2006) had 16 AFL teams. Thus, further prospective research is needed in Gaelic football due to the lack of numbers in this current study.

Limitations

There are many limitations to this study. Firstly, the study was conducted in only one elite male Gaelic football team with only 38 participants. The team was currently in division one and may have greater access to resources than other teams. Therefore, the results cannot be generalised across all levels and codes of Gaelic games. The team had access to strength and conditioning coaches and players were undergoing a specific programme based on their needs. This multifactorial individualized approach is welcomed however it may have had an uncontrolled impact on risk factors that were being tested. Another limitation was that tester reliability wasn't conducted for the tests. Unfortunately, due to the COVID-19 pandemic, there was a change to the Gaelic football calendar, which meant the study was not carried out over the inter-county league and championship as planned. The shorter study duration may have impacted this finding, and future studies should be completed over a longer duration and investigate injured players across different time points. Additionally, tracking players' individual running volumes outside of matches or training sessions was not controlled for in this study. Future studies should focus on more teams, increased participant numbers and more extended study duration.

4.5 Conclusion

In preseason screening, previous injury, a non-modifiable risk factor, had the largest association as a risk factor for a hamstring injury. The only modifiable risk factor or physical test associated with injury was increased jump height on the CMJ implying that there could be a muscle imbalance. It was identified that injured players completed greater high-intensity efforts and high-speed running distances than their uninjured counterparts. This is critical for coaches as appropriate stimulus is needed for performance enhancement but too much exposure to high-speed running could be associated with hamstring injury. Similarly, coaches must thoroughly understand the demands of Gaelic football to plan the optimum dose to enhance the fitness-fatigue response in players and to prevent hamstring injuries during matches. Therefore monitoring individual players' high-speed running from week to week and limiting over-exposure and rapid spikes is recommended to mitigate the risk of hamstring injuries in Gaelic games. However, there was no difference in any of the performance tests (CMJ, Nordic hamstring test and knee-to-wall) in this study between injured and uninjured players.

Link to Chapter 5

From Chapter 4, it was found that high-speed running exposure was significantly different on the week of injury for injured and uninjured players. Similarly, for injured players high-speed running exposure was significantly greater during the injury block than the pre-injury block suggesting that rapid changes in high-speed running is a risk factor for hamstring injuries. Therefore it is recommended that players and coaches monitor high-speed running exposure and increase the exposure gradually and in a controlled manner. At preseason the best predictors of hamstring injury were non-modifiable risk factors previous injury and increased age. Similarly, it was found that increased jump height on the CMJ was also a predictor of a hamstring injury. However, increased power is a necessary component of sports performance, but strength and conditioning coaches should aim for symmetrical increases in strength to avoid large imbalances. Therefore, to limit the impact of these risk factors for hamstring injury in Gaelic football, injury prevention interventions to prevent need to be implemented. One such intervention is the use of injury prevention exercise programmes. The third and fourth stages of the TRIPP framework are to develop an injury prevention exercise programme and assess its effectiveness under controlled conditions (Finch, 2006). Stages 3 and 4 have been completed in relation to Gaelic games. Several programmes have been developed (the GAA15, the Activate GAA Warm-up, the Camogie Injury prevention exercise programme, and The Athletic Development and Injury Prevention Program). The GAA 15 and the Activate GAA warm up have been shown to be effective at reducing injury and increasing neuromuscular capacities in a controlled environment. However, it remains to be seen if these are adopted in the real-world setting as injury rates remain high in Gaelic games. This makes the understanding of factors investigating the awareness and use of these programmes in the real world critical (Stage 5 of the TRIPP framework).

To address this limitation, Chapter 5 aims to investigate Gaelic games players' awareness and use of injury prevention exercise programmes. Further, we aimed to establish if player differences in awareness, use, and attitudes exist between genders and levels of play. Previous research suggests that awareness and use of injury prevention exercise programmes is low. However for these programmes to be effective in the real world context, stakeholders must first be aware of them, accept them and use them as intended. This study also aimed to identify perceived barriers and facilitators to injury prevention exercise programme so that the programmes fit within the context of the game.

Chapter 5 Study 3 - Gaelic Games Players' Awareness and Use of, and Attitudes Towards Injury Prevention.

Teahan, C., Whyte, E., and O'Connor, S. 2023 “Gaelic Games Players’ Awareness and Use of, and Attitudes towards Injury Prevention Exercise Programmes.” *Physical Therapy in Sport.*

5.1 Introduction

Gaelic games include Gaelic football and hurling (governed by the Gaelic Athletic Association (GAA)), Ladies Gaelic football (governed by the Ladies Gaelic Football Association (LGFA)) and Camogie (governed by the Camogie Association) and are popular sports native to Ireland. The games are played on an amateur basis, yet the time commitment for elite Gaelic games is comparable to that of professional sports (Murphy et al., 2010). Players can participate in one or more of the games concurrently, with different levels of competition ranging from local clubs to national inter-county competitions (Sullivan et al., 2020). Gaelic games are multidirectional sports requiring players to engage in a large amount of unpredictable high-intensity activity (O’Connor et al., 2022), as well as requiring them to jump, land, change directions rapidly, accelerate and decelerate, and perform evasive moves like planting and cutting (Sullivan et al., 2020). Injury rates can vary between sports and levels, but match injury rates are high (26.4-102.5 injuries/1000 hours), and lower extremity injuries are most frequent across all the sports (Murphy et al., 2012; Buckley and Blake, 2018; O’Connor et al., 2021; Murphy et al., 2010).

Utilising injury prevention exercise programmes is one strategy to decrease injury rates in team sports (Sly et al., 2022). Several Gaelic games-specific injury prevention exercise programmes have been developed, including the GAA15 (GAA.ie), the Activate GAA Warm-up (Ulster.GAA.ie), the Camogie Injury Prevention Programme (CIPP) (Camogie.ie), and The Athletic Development and Injury Prevention Program (Ladiesgaelic.ie). Three studies have investigated the efficacy of the implementation of the GAA15, showing it to reduce the risk of lower limb injuries in adolescent hurlers (Kelly and Lodge, 2018) and collegiate Gaelic games players (Schlingermann et al., 2018), as well as increase neuromuscular performance (Schlingermann et al., 2018; O’Malley et al., 2017). One study has found that the Activate GAA Warm-up increases neuromuscular performance (O’Connor et al., 2022). There is no current research on the efficacy of The Athletic Development and Injury Prevention Program. Limited evidence shows that both the GAA15 and the Activate GAA Warm-up may be effective, but there is less research on its adoption, compliance, and maintenance. Positive injury prevention exercise programmes are rarely fully embraced by a sporting population and are poorly adopted and complied with, which prevents them from having the desired impact in the "real world" (Barden et al., 2021; Donaldson et al., 2017). Anecdotally, the use of injury prevention exercise programmes in Gaelic games is considered low (O'Connor et al., 2020). The use and awareness of injury prevention exercise programmes in Gaelic games players have only been investigated in one study conducted in Camogie (O'Connor et al., 2020). Camogie players had both low awareness (13.9%) and use (11.8%) of injury prevention exercise programmes (O'Connor et al., 2020), which was similar to English schoolboy rugby players (awareness (13%), use (11%)) (Barden et al., 2021), and professional soccer players (awareness (9%), use (2%)) (O'Brien and Finch, 2017).

Understanding Gaelic games players' (end users) perceptions and attitudes towards injury risk and prevention are crucial to improving the adoption, implementation, and maintenance of injury prevention exercise programmes (Barden et al., 2021; Donaldson et al., 2017). It is possible to increase their success, particularly in community-based sports, by understanding and addressing any issues or barriers to implementing injury prevention exercise programmes (Finch and Donaldson, 2010). Without better knowledge of how to use evidence-based interventions in the real world, future advancements in injury prevention are unlikely to be made (Donaldson et al., 2017). Prior experiences, perceptions of vulnerability, perceived seriousness, perceptions of the efficacy of current preventive measures, awareness of preventative measures, and social influences all contribute to changes in the protective behaviour (Verhagen et al., 2010). The RE-AIM framework emphasises that interventions must be made available to the target group, adopted by them, used as intended, and then sustained over time for desired behaviours to be reached (Finch, 2011). Therefore, this study aimed to determine the awareness and use of injury prevention exercise programmes in Gaelic games players. Further, we aimed to investigate the attitudes of Gaelic games players towards injury and injury prevention and if player differences in awareness, use, and attitudes exist between genders and levels of play. This study also aimed to identify perceived barriers and facilitators to injury prevention exercise programme adoption in Gaelic games and determine the level of access to different coaches/medical staff amongst genders and levels of play.

5.2 Methods

5.2.1 Participants and study design

An anonymous online cross-sectional survey of adult Gaelic games players' awareness, use and attitudes towards injury and injury prevention was conducted. Adult men or women (18 years of age and older) Gaelic games players currently playing Gaelic football, Ladies Gaelic football, hurling, or Camogie were eligible to complete the survey. Ethical approval was granted by Dublin City University's Research Ethics Committee (DCUREC/2021/137). Before completing the survey, participants read a plain language statement and provided informed consent, which took 14.3 ± 4.6 minutes to complete on average.

5.2.2 Instrumentation

This anonymous survey was adapted from previous research (O'Connor et al., 2020; Møller et al., 2021; Fokkema et al., 2019; Wilke et al., 2018; Martinez et al., 2017; McKay et al., 2014; Finch, 2002) for the Gaelic games context. The questionnaire was then validated using a review process by experts in the fields of injury prevention (n = 3), coaching (n = 2), and sport science (n = 1), whom all had a background in academia. Each question was assessed and scored between 1 and 5 for clarity, comprehensiveness, and appropriateness. Questions with an average score of less than 4/5 were revised or eliminated (Mawson et al., 2018). Additionally, suggestions for questions and survey improvement were requested. Finally, the survey was piloted on 18 players across all four codes of Gaelic games.

Section 1 consisted of 6 demographic questions. Players were asked their gender, age, the sport they played, how many years of playing experience, their level of participation and where their club was located. Section 2 (5 questions) investigated access to coaches/medical personnel and if preseason screening was conducted with their team (O'Connor et al., 2020; Wilke et al., 2018). Section 3 (2 questions) examined players' awareness of specific Gaelic games injury prevention exercise programmes (O'Connor et al., 2020). Section 4 (6 questions) investigated players' current use of injury prevention exercise programmes and gathered information on by whom it was delivered, the frequency of delivery and for how long in each session (O'Connor et al., 2020; McKay et al., 2014). Section 5 (3 questions) investigated how players rated different interventions for injury prevention and how often they used them (Fokkema et al., 2019; Wilke et al., 2018; Martinez et al., 2017). Section 6 (3 questions) explored players' levels of agreement on positive and negative attitudes towards injury and injury prevention (15 statements), and also attitudes to safety behaviours and perceived behavioural control factors relating to the level of support received or expected to be received if the player had been injured or were to be injured (7 statements) (O'Connor et al., 2020; Møller et al., 2021; Martinez et al., 2017; Finch, 2002). The final section consisted of 2 questions and investigated barriers (17 statements) and facilitators (13 statements) to successful injury prevention use (O'Connor et al., 2020). A 5-point Likert scale ranged from "strongly disagree" to "strongly agree."

5.2.3 Procedures

A sample size calculation was conducted using Qualtrics online calculator (SAP America Inc., Seattle, WA) and was determined to be 384. The estimated population size was 300000, and a margin of error of 5% was used. A recruitment email was sent to every county board secretary (n=104) and club (n=2157) secretary in Ireland, including information and a survey link. We requested the county board and club secretaries to distribute the survey to all adult playing members. Reminder emails were sent 3- and 6 weeks post-initial email. Additionally, the survey was advertised and promoted via social media and word of mouth. The survey was delivered online using Qualtrics (SAP America Inc., Seattle, WA) and was open for responses from May 13 to July 15, 2022.

5.2.4 Data Analysis

Responses were exported to SPSS Statistics (version 27, IBM Corporation). Data were screened for omissions or invalid responses. Missing data were treated case by case and removed from analysis if at least 80% of the questionnaire wasn't completed. Frequencies and descriptive statistics were generated from eligible responses.

A chi-squared test assessed differences in the use and awareness of injury prevention exercise programmes and access to coaches/medical personnel between elite (representing their club and county team) and non-elite (representing their club team only) Gaelic games players and men and women Gaelic games players. An attitude towards injury prevention scale was created from 10 statements by assigning a score ranging from 1 to all "strongly disagree" responses and 5 to all "strongly agree" responses, as previously used (O'Connor et al., 2020). Negative statements were reversed to ensure that a higher score on the scale corresponds to a more positive view towards injury prevention (O'Connor et al., 2020). Similarly, an attitude towards injury scale was created from 7 statements. Adequate internal consistency was observed for the attitudes towards injury prevention using Cronbach's alpha (0.75) and the injury scale using the mean inter-item correlation (0.2). Data were non-normally distributed, and Mann-Whitney *U* tests were used to identify significant differences between gender and level of play for positive attitudes towards injury and injury prevention exercise programmes. Effect sizes were classified as small (0.1), medium (0.3), and large (0.5) (Cohen 2013). A Pearson's correlation was used to identify the relationship between age and attitudes towards injury prevention, and the relationship was classified as small r=0.10 to r=0.29, medium r=0.30 to r=0.49 and large r=0.50 to r=1.00 (Cohen, 1988). Statistical significance was set a priori at 0.05.

5.3 Results

The questionnaire was opened 1,244 times, but 504 responses were insufficient as only consent was provided or less than 80% of the questionnaire was completed. Thus, 704 responses (413 male, 289 female and two non-binary/third gender) were included in the analysis. Participants were predominantly non-elite (81.1%), compared with elite (18.9%). The breakdown of respondents in each Gaelic games code is reported in Table 5.1.

Table 5. 1. Total number and percentage of players in each Gaelic Games code.

Gaelic games code	**Total % (n) (n=703)**	**Elite % (n) (n=131)**	**Non-elite % (n) (n=563)**
Total	-	18.9 (131)	81.1 (563)
Gaelic football	35.8 (252)	31.3 (41)	36.9 (208)
Hurling	11.7 (82)	16.6 (23)	10.5 (59)
Dual Gaelic football and Hurling	11.4 (80)	5.3 (7)	12.6 (71)
Ladies Gaelic football	21.5 (151)	19.1 (25)	21.8 (123)
Camogie	10.4 (80)	13.7 (18)	9.6 (54)
Dual - Ladies Gaelic football and Camogie	9.2 (65)	13.0 (17)	8.5 (48)

%: percentage; n: sample size.

5.3.1 Awareness and use of specific injury prevention exercise programmes for Gaelic games

Over a third of men Gaelic games players (34.6%) (Table 5.2) stated that they were aware of a specific Gaelic games injury prevention exercise programme, with fewer women Gaelic games players stating that they were aware of a Gaelic games injury prevention exercise programme (29.1%); however, this was not statistically significant (*p*=0.30, *phi*=0.06). Of the participants that were aware of a Gaelic games injury prevention exercise programme only 35.9% (n=46) of men (GAA 15 =33.6%, n=43; Activate GAA warm-up =4.7%, n=6; CIPP=0.8%, n=1) and 50% (n=38) of women (GAA 15 =47.4%, n=36; Activate GAA warm-up =3.9%, n=6; CIPP =1.3%, n=1; The Athletic Development and Injury Prevention Warm Up =5.3%, n=4) correctly identified an injury prevention exercise programme. A greater number of elite players (38.7%) were aware of injury prevention exercise programmes than non-elite players (30.7%); however, this difference was not significant (*p*=0.10, *phi*=0.07).

Table 5. 2. Gaelic Games Players Awareness, Use of and the Type of Injury Prevention Exercise Programme Type is used.

Sport/Gender	Awareness % (n)	Use % (n)	Injury prevention exercise programme used % (n)						
			GAA 15	Activate GAA Warm-up	Camogie Injury Prevention Programme	The Athletic Development and Injury Prevention Warm Up	Modified Injury prevention Exercise Programme	One I developed myself	Other
Total	32.4 (205)	31.7 (200)	32.5 (65)	65.5 (131)	4.5 (9)	9.0 (18)	18.0 (36)	23.5 (47)	26.5 (53)
				Gender					
Men's GG	34.6 (128)	35.1 (129)	23.3 (35)	58.1 (75)	0.0 (0)	10.9 (14)	3.9 (5)	26.4 (34)	22.5 (29)
Women's GG	29.1 (76)	26.5 (69)	42.0 (29)	78.2 (54)	11.6 (8)	5.8 (4)	15.9 (11)	18.8 (13)	34.8 (24)
				Gaelic games code					
Gaelic football	35.2 (83)	38.3 (90)	10.6 (25)	24.3 (57)	1.1 (1)	10.0 (9)	16.7 (15)	24.4 (22)	22.2 (20)
Hurling	33.8 (22)	33.8 (22)	18.2 (4)	45.5 (10)	0.0 (0)	9.1 (2)	18.2 (4)	27.3 (6)	22.7 (5)
Dual Gaelic football & Hurling	33.8 (24)	25.7 (18)	38.9 (7)	50.0 (9)	0.0 (0)	16.7 (3)	33.3 (6)	33.3 (6)	22.2 (4)
Ladies Gaelic football	35.8 (48)	27.8 (37)	45.9 (17)	86.5 (32)	0.0 (0)	7.4 (2)	16.2 (6)	18.9 (7)	35.1 (13)
Camogie	23.1 (15)	21.5 (14)	28.6 (4)	71.4 (10)	21.4 (3)	0.0 (0)	7.1 (1)	14.2 (2)	42.9 (6)
Dual Ladies Gaelic football & Camogie	21.0 (13)	30.6 (19)	42.1 (8)	68.4 (13)	26.3 (5)	10.5 (2)	21.0 (4)	21.0 (4)	26.3 (5)

Level of play									
Elite	38.7 (46)	30.3 (36)	22.2 (8)	52.8 (19)	2.8 (1)	16.7 (6)	25.0 (9)	30.6 (11)	30.6 (11)
Non-elite	30.7 (157)	32.2 (164)	34.1 (56)	68.3 (112)	4.9 (8)	7.3 (12)	16.5 (27)	22.0 (36)	25.9 (42)

%: percentage; n: number; GG: Gaelic games.

In total, 31.7% used injury prevention exercise programmes, with men Gaelic games players (35.1%) having significantly higher use of injury prevention exercise programmes compared with women (26.5%) with a small effect size (*p*=0.04, *phi*=0.13). However, a similar number of men (28.8%) and women (29.2%) were unsure if they used an injury prevention exercise programme. The most frequently used Gaelic games injury prevention exercise programmes across all codes were the Activate GAA Warm-up (65.5%) and the GAA 15 (32.5%). There was no significant difference between elite (30.3%) and non-elite (32.2%) Gaelic games players for the use of injury prevention exercise programmes (*p*=0.90, *phi*=0.02). The injury prevention practices commonly used were running (73.4%), muscle activation (66.8%) and sprinting (66.2%). Balance (23.6%), contact primers (25.0%) and jumping & landing mechanics (41.4%) were the injury prevention practices that were least used. For the players who reported using an injury prevention exercise programme, they were primarily delivered by the athletic development coach (strength and conditioning/fitness coach) (39.5%) or the head coach (33.8%) (Table 5.3). Injury prevention exercise programmes are completed mostly at every training session and match (46.3%, n = 149). Most injury prevention exercise programmes took between 6 to 10 minutes (34.3%) or 11 to 15 minutes (27.1%).

Table 5. 3. Delivery, Frequency, and Duration of Injury Prevention Exercise Programmes in Gaelic Games.

***Who is responsible for the delivery of an injury prevention exercise programme with your team? (n=382)* - % (n)**	
Coach (head)	33.8 (129)
Coach (other)	18.8 (72)
Athletic development coach	39.5 (151)
Medical personnel (Athletic therapist/Physiotherapist)	15.2 (58)
Player led	18.3 (70)
Self-administered outside of training	15.2 (58)
***How often are injury prevention exercise programmes carried out by your team (n=322)* - % (n)**	
Every training	24.2 (78)
Every match	1.2 (4)
Every training and match	46.3 (149)
One training a week	5.9 (19)
Less than one training/match a week	8.1 (26)
Completed outside of training and match time	13.4 (43)
Other	0.9 (3)
***How long does your team spend implementing injury prevention exercise programmes (n=361)* - % (n)**	
None	11.6 (42)
1 to 5 mins	18.0 (65)
6 to 10 mins	34.3 (124)
11 to 15 mins	27.1 (98)
16 to 20 mins	6.1 (22)
> 20 mins	2.8 (10)

%: percentage; n: number.

5.3.2 Players' attitudes towards injury and injury prevention exercise programmes

Gaelic games players (68.2%) agreed or strongly agreed that injuries were a problem with their team, while 96.2% agreed or strongly agreed that injuries could shorten their playing career (Table 5.4). Most respondents (70.4%) believed that an injured player should be fully rehabilitated before returning to play. Gaelic games players predominantly disagreed or strongly disagreed (70.1%) that it was safe to continue playing while injured. However, only 34.1% did not feel pressure to play while injured. There were no significant differences in attitudes towards injury prevention for the level of play (r=0.06, p=0.22) or gender (r=0.14, p=0.06) or attitudes towards injury for the level of play (r=0.03, p=0.37). However, women (median = 22) Gaelic games players had a significantly more positive attitude towards injury compared to men (median = 22) with medium effect size (r=0.39, p=0.01). There was no statistically significant relationship between age and attitudes towards injury prevention (r=0.04*;* p=0.38*).*

5.3.3 Barriers and Facilitators

Fewer injuries (90.7%) were the greatest facilitators of using an injury prevention exercise programme, while 83.5% agreed that more training in delivering injury prevention exercise programmes would encourage them to participate (Table 5.5). Players believed the motivation of the coach (71.5%) had a large effect on the player's motivation to take part in injury prevention exercise programme, while 33.5% of players feel that their team needs someone with the appropriate skill to lead them in an injury prevention exercise programme.

5.3.4 Injury prevention practice

The most popular injury prevention practices Gaelic games players always do were warm-up (74.7%) and stretching (53.8%) (Table 5.6). Respondents frequently reported that training in landing technique (40.5%) and balance training (35.5%) were never performed as part of injury prevention. Adequate sleep, good nutrition and a warmup were the interventions that were rated most effective amongst Gaelic games players.

Table 5. 4. Players' Attitudes Towards Injury and Injury Prevention Exercise Programme.

	Strongly disagree % (n)	**Disagree** % (n)	**Neither agree nor disagree** % (n)	**Agree** % (n)	**Strongly agree** % (n)
Negative statements to injury and injury prevention					
Injuries are an issue with my team (n=610)	1.6 (10)	12.5 (76)	17.7 (108)	46.7 (285)	21.5 (131)
Injuries can shorten a player's career (n=610)	0.8 (5)	0.8 (5)	2.1 (13)	35.9 (219)	60.3 (368)
Injuries can cause physical problems later in life (n=609)	1.0 (6)	1.0 (6)	2.8 (17)	39.7 (242)	55.5 (338)
Injuries have a negative impact on team performance (n=609)	0.7 (4)	2.1 (13)	9.4 (57)	42.5 (259)	45.3 (276)
Gaelic games players are at a high risk of suffering an injury (n=609)	0.5 (3)	3.0 (18)	12.6 (77)	48.9 (298)	35.0 (213)
Injury prevention programmes cost too much (n=606)	5.0 (30)	24.8 (150)	43.7 (265)	22.1 (134)	4.5 (27)
Injury prevention programmes takes up too much training time away from necessary tasks (n=608)	8.1 (49)	41.3 (251)	32.9 (200)	15.1 (92)	2.6 (16)
Positive statements to injury and injury prevention					
It's important for coaches to have current knowledge of injury prevention programmes (n=607)	0.3 (2)	0.7 (4)	3.6 (22)	56.7 (344)	38.7 (235)
It's important for players to have current knowledge of injury prevention programmes (n=605)	0.2 (1)	0.5 (3)	3.6 (22)	58.7 (355)	37.0 (224)
Injury prevention is important during training sessions (n=605)	0.3 (2)	0.8 (5)	3.8 (23)	57.9 (350)	37.2 (225)
Activities included in injury prevention programmes are relevant and beneficial to players (n=606)	0.5 (3)	0.3 (2)	4.8 (29)	58.3 (353)	36.1 (219)

I believe that using an injury prevention programme will reduce the number of injuries for my team (n=604)	0.0 (0)	1.7 (10)	7.0 (42)	54.1 (327)	37.3 (225)
I believe that injuries are preventable (n=606)	1.0 (6)	8.1 (49)	22.8 (138)	50.3 (305)	17.8 (108)
Exercises which have been shown to prevent injuries should be performed by Gaelic games players (n=604)	0.7 (4)	0.8 (5)	6.3 (38)	56.3 (340)	35.9 (217)
Exercises to prevent injuries should be varied and progressed over time (n=606)	0.0 (0)	1.3 (8)	7.3 (44)	62.0 (376)	29.4 (178)
Attitudes on Safety Behaviours					
I believe that it is safe to play with injuries (n=609)	20.2 (123)	49.9 (304)	23.6 (144)	6.1 (37)	0.2 (1)
I am willing to play with injuries (n=609)	4.6 (28)	15.8 (96)	24.0 (146)	48.8 (297)	6.9 (42)
I admire Gaelic games players who continue to play when injured (n=609)	11.7 (71)	31.7 (193)	33.0 (201)	21.0 (128)	2.6 (16)
I feel under pressure to play when injured (n=607)	7.7 (47)	26.4 (160)	21.4 (130)	33.3 (202)	11.2 (68)
Perceived behavioural control factors relating to the level of support received, or expected to be received, if the player had been injured or were to be injured					
I believe that players should be fully rehabilitated before playing again after they have suffered an injury (n=609)	1.1 (7)	7.1 (43)	21.3 (130)	46.6 (284)	23.8 (145)
The coach assists players when injured (n=608)	3.3 (20)	11.2 (68)	21.5 (131)	48.5 (295)	15.5 (94)
The club assist players with medical issues (n=607)	8.2 (50)	14.7 (89)	19.8 (120)	41.4 (251)	16.0 (97)

%: percentage; n: number.

Table 5. 5. Barriers and Facilitators to Successful Injury Prevention.

	Strongly disagree % (n)	**Disagree** % (n)	**Neither agree nor disagree** % (n)	**Agree** % (n)	**Strongly agree** % (n)
Facilitators to injury prevention exercise programmes					
Observing elite teams (n=572)	2.6 (15)	8.0 (46)	15.9 (91)	56.8 (325)	16.6 (95)
Better resources (n=572)	1.9 (11)	5.4 (31)	10.1 (58)	61.0 (349)	21.5 (123)
More training in the delivery (n=571)	1.1 (6)	4.0 (23)	11.4 (65)	63.2 (361)	20.3 (116)
The introduction of a ball or skills (n=571)	1.2 (7)	5.1 (29)	10.7 (61)	59.0 (337)	24.0 (137)
A player in my team having a serious injury (n=572)	3.0 (17)	14.2 (81)	21.2 (121)	46.5 (266)	15.2 (87)
I would run faster (n=572)	1.0 (6)	5.4 (31)	12.1 (69)	51.7 (296)	29.7 (170)
I would jump higher (n=571)	1.2 (7)	6.1 (35)	14.4 (82)	49.2 (281)	29.1 (166)
I would have fewer injuries (n=571)	0.5 (3)	1.1 (6)	7.7 (44)	50.4 (288)	40.3 (230)
I would feel comfortable leading IPEP (n=569)	7.9 (45)	24.1 (137)	18.1 (103)	35.1 (200)	14.8 (84)
I would feel comfortable with a teammate leading IPEP (n=570)	1.6 (9)	6.5 (37)	11.9 (68)	58.6 (334)	21.4 (122)
I would feel comfortable with my coach leading IPEP (n=572)	1.4 (8)	7.7 (44)	12.1 (69)	53.7 (306)	25.1 (143)
I would feel comfortable with my athletic development coach leading IPEP (n=570)	0.7 (4)	1.4 (8)	9.8 (56)	44.7 (255)	43.4 (248)
I would feel comfortable with my AT/Physiotherapist leading IPEP (n=569)	0.5 (3)	2.1 (12)	9.0 (51)	47.1 (268)	41.3 (235)
Barriers to injury prevention exercise programmes					
My teams training sessions are not long enough (n=560)	9.2 (54)	41.1 (241)	20.1 (118)	25.1 (147)	4.4 (26)

IPEP is too long (n=584)	4.5 (26)	39.2 (229)	43.7 (255)	11.5 (67)	1.2 (7)
Exercises too difficult (n=583)	14.2 (83)	59.2 (345)	20.6 (120)	5.7 (33)	0.3 (2)
Exercises are boring (n=583)	8.1 (47)	38.3 (223)	24.0 (140)	27.1 (158)	2.6 (15)
The programme is too rigid (n=583)	6.2 (36)	39.3 (229)	41.5 (242)	12.3 (72)	0.7 (4)
I am not motivated enough (n=581)	12.7 (74)	42.5 (247)	22.2 (129)	21.0 (122)	1.5 (9)
There is no ball/hurley involved (n=584)	6.3 (37)	22.8 (133)	25.7 (150)	40.6 (237)	4.6 (27)
There is no training available to teach me (n=582)	6.0 (35)	33.7 (196)	21.1 (123)	32.1 (187)	7.0 (41)
I don't believe that using an IPEP will reduce injuries (n=583)	24.4 (142)	55.2 (322)	10.1 (59)	8.7 (51)	1.5 (9)
My team doesn't have someone with the appropriate skill/knowledge (n=582)	13.9 (81)	39.9 (232)	12.7 (74)	23.4 (136)	10.1 (59)
The programme causes soreness (n=581)	10.8 (63)	47.0 (273)	28.1 (164)	12.9 (75)	1.0 (6)
I do not have a history of injury (n=580)	34.8 (202)	42.1 (244)	5.7 (33)	11.9 (69)	5.5 (32)
The motivation of the coach affects the players motivation to do IPEP (n=582)	1.7 (10)	12.7 (74)	14.1 (82)	54.0 (314)	17.5 (102)
I do not have enough knowledge how to use it (n=580)	6.7 (39)	30.7 (178)	17.6 (102)	35.9 (208)	9.1 (53)
My coach does not have enough knowledge how to use it (n=580)	6.2 (36)	30.5 (177)	21.7 (126)	29.0 (168)	12.6 (73)
I am not sure if IPEP is beneficial to the team (n=580)	26.9 (156)	58.4 (339)	9.8 (57)	4.0 (23)	0.9 (5)
My coach is not sure if IPEP is beneficial to the team (n=589)	15.2 (88)	43.4 (251)	29.5 (171)	9.5 (55)	2.4 (14)

%: percentage; n: number; IPEP: injury prevention exercise programme; AT: athletic therapist.

Table 5. 6. Intervention Usage and Players Rating of the Effectiveness of the Interventions for Prevention of Injury in Gaelic Games.

	Which interventions of injury prevention are used with your team					*How effective do you rate the following interventions for injury prevention*						
	Never % (n)	**Sometimes** % (n)	**About half the time** % (n)	**Most of the time** % (n)	**Always** % (n)	**Total**	**Gaelic football**	**Hurling**	**Dual Gaelic football & Hurling**	**Ladies Gaelic football**	**Camogie**	**Dual Ladies Gaelic football & Camogie**
Activation	21.8 (136)	29.5 (184)	5.5 (34)	18.1 (113)	25.0 (156)	6.3±2.1	6.2±2.2	6.7±2.1	5.9±2.1	6.3±2.0	6.6±2.0	6.1±2.0
Active Recovery	11.1 (68)	33.9 (208)	16.3 (100)	25.9 (159)	12.9 (79)	7.1±1.9	6.9±1.9	7.1±2.1	7.2±1.9	7.5±1.8	7.3±1.6	7.0±1.9
Adequate sleep	6.4 (39)	12.1 (74)	12.5 (77)	47.4 (291)	21.7 (133)	8.2±1.9	8.5±2.0	8.3±1.7	8.2±1.9	8.5±1.9	8.4±1.8	8.3±2.2
Agility	7.4 (46)	30.2 (187)	25.5 (158)	24.7 (153)	12.3 (76)	7.4±1.8	7.1±1.8	7.0±1.6	7.1±1.8	7.8±1.7	7.6±1.7	7.6±1.7
Balance	35.5 (219)	36.5 (255)	13.1 (81)	10.2 (63)	4.7 (29)	6.2±2.1	6.0±2.0	5.7±1.8	5.8±2.3	6.6±2.1	6.8±2.2	6.7±2.0
Compression garments	62.3 (385)	25.4 (157)	6.3 (39)	4.2 (26)	1.8 (11)	4.1±2.2	3.8±2.0	3.8±1.8	4.5±2.6	4.2±2.2	4.8±2.3	4.4±2.2
Cool down	5.0 (31)	18.9 (117)	12.5 (77)	27.3 (169)	36.2 (224)	5.9±2.5	5.2±2.3	5.6±2.2	6.0±2.5	6.6±2.7	6.5±2.6	6.5±2.2
Core stability	14.9 (92)	33.0 (304)	24.4 (151)	19.9 (123)	7.9 (49)	6.7±2.1	6.5±2.1	6.9±2.1	6.6±2.2	6.9±2.2	7.2±2.0	6.8±2.0
Cryotherapy	50.9 (314)	35.3 (218)	6.8 (42)	5.7 (35)	1.3 (8)	5.5±2.5	5.5±2.6	5.0±2.3	5.9±2.5	5.4±2.7	5.6±2.5	5.4±2.4
Education	44.8 (278)	34.7 (215)	11.0 (68)	6.9 (43)	2.6 (16)	6.1±2.5	6.1±2.4	5.8±2.6	6.0±2.4	6.6±2.1	5.5±2.7	6.4±2.4
Endurance	7.5 (46)	18.5 (114)	28.1 (173)	34.7 (214)	11.2 (69)	6.5±2.1	6.4±2.2	6.1±2.1	6.9±1.9	6.8±2.1	6.6±2.2	6.4±2.0
Foam rolling	29.8 (184)	33.5 (207)	14.9 (92)	14.1 (87)	7.8 (48)	5.2±2.5	4.7±2.5	5.1±2.4	5.0±2.5	5.5±2.5	6.3±2.6	5.4±2.5
Good nutrition	7.1 (44)	14.2 (88)	18.1 (112)	43.2 (267)	17.3 (107)	8.2±1.8	8.0±1.9	8.1±1.6	8.1±1.6	8.4±1.6	8.4±1.7	8.2±1.7

Knowledge of the rules	16.6 (103)	21.5 (133)	16.5 (102)	27.0 (167)	18.4 (114)	5.8±2.8	5.4±2.8	5.6±2.5	5.7±2.6	6.2±2.7	5.9±3.2	6.8±2.8
Load management	16.5 (102)	25.8 (159)	24.0 (148)	24.8 (153)	8.9 (55)	7.7±2.1	8.0±1.8	7.7±1.7	7.6±2.1	7.4±2.4	7.0±2.3	7.7±2.4
Massage	40.6 (252)	40.0 (248)	111.6 (72)	6.0 (37)	1.8 (11)	5.7±2.5	5.4±2.5	5.1±2.2	5.9±2.5	5.8±2.6	6.5±2.3	6.3±2.3
Orthoses	75.8 (466)	9.8 (60)	3.4 (21)	3.4 (21)	7.6 (47)	4.4±2.5	4.1±2.4	4.1±2.3	4.6±2.5	4.8±2.6	4.6±2.7	4.7±2.1
Plyometrics	15.8 (98)	29.4 (182)	20.2 (125)	21.0 (130)	13.7 (85)	6.7±2.2	6.5±2.2	6.6±1.7	6.5±2.4	7.2±2.1	6.6±2.3	7.0±2.1
Recovery boots	67.3 (416)	24.6 (152)	5.2 (32)	2.1 (13)	0.8 (5)	4.3±2.4	4.0±2.1	4.1±2.4	4.4±2.7	4.4±2.5	5.1±2.5	4.9±2.4
Resistance training	14.9 (92)	28.3 (175)	19.4 (120)	23.1 (143)	14.2 (88)	7.1±2.2	7.1±1.9	6.9±2.0	6.8±2.3	7.2±2.0	7.1±2.0	7.1±1.8
Speed training	7.8 (48)	23.3 (144)	25.9 (160)	29.8 (184)	13.3 (82)	7.1±2.0	7.2±1.9	6.7±2.1	7.1±2.2	7.1±2.2	7.2±2.0	6.8±2.1
Stretching	1.6 (10)	7.9 (49)	9.4 (58)	27.2 (168)	53.8 (332)	7.7±2.2	7.5±2.4	7.0±2.2	7.7±1.9	8.1±2.1	8.3±2.0	7.9±2.2
Taping	25.3 (157)	37.6 (233)	14.2 (88)	13.7 (85)	9.2 (57)	5.4±2.5	5.2±2.5	4.8±2.3	5.6±2.4	5.6±2.5	5.9±2.4	5.5±2.4
Training of functional movements	32.4 (201)	34.4 (213)	15.3 (95)	12.4 (77)	5.5 (34)	7.0±2.1	7.2±2.0	6.6±2.2	6.4±2.4	7.0±2.1	7.4±2.0	7.6±1.9
Landing technique	40.5 (251)	28.4 (176)	12.3 (76)	11.6 (72)	7.1 (44)	7.0±2.1	6.7±2.1	6.5±2.1	6.5±2.2	7.3±2.2	7.4±2.1	7.9±1.7
Proper sports technique	22.3 (138)	31.2 (193)	16.5 (102)	19.7 (122)	10.2 (63)	7.4±2.0	7.2±2.0	6.7±2.1	7.2±1.9	7.8±1.9	7.8±1.9	7.8±1.8
Warmup	0.3 (2)	4.3 (27)	3.2 (20)	17.4 (108)	74.7 (464)	7.8±2.1	7.7±2.0	7.0±2.3	8.1±1.8	8.1±2.2	7.9±2.2	7.8±2.1

%: percentage; n: number.

5.3.5 Access to Athletic Development Coaches and medical personnel

Over half (56.9%) of Gaelic games players had access to an athletic development coach. Elite Gaelic games players (77.5%) had greater access to an athletic development coach than non-elite players (51.9%), which was statistically significant ($p<0.01$, $phi=-0.20$). Similarly, a greater proportion of women Gaelic games players (55.7%) had no access to an athletic development coach compared with men players (34.4%) ($p<0.01$, $phi=0.21$). Just 15.3% of participants had access to medical personnel every match and training, with 15.0% never having access (Table 5.7). Almost 2 in every 5 (38.8%) elite players completed pre-season testing, significantly more than non-elite players (22.9%, $p<0.01$, $phi=-0.15$). The athletic development coach (68.0%) and the main coach (27.0%) were predominantly responsible for the delivery of preseason screening. Strength testing, bilateral jump testing and flexibility testing were the most popular tests/methods used for preseason screening.

Table 5. 7. Gaelic games players' access to medical personnel.

	Every training and match % (n)	One training a week and every match % (n)	Every match only % (n)	Championship match only % (n)	Every training only % (n)	One training a week only % (n)	Occasional % (n)	Never % (n)
Total	15.3 (105)	10.2 (70)	31.6 (217)	7.1 (49)	0.3 (2)	0.9 (6)	19.5 (134)	15.0 (103)
Gender								
Men's Gaelic games	18.3 (74)	12.9 (52)	38.6 (156)	5.2 (21)	0.5 (2)	1.5 (6)	15.8 (64)	7.2 (29)
Women's Gaelic games	11.1 (31)	6.4 (18)	21.8 (61)	9.6 (27)	0.0 (0)	0.0 (0)	25.0 (70)	26.1 (73)
Gaelic games code								
Gaelic football	19.6 (49)	12.4 (31)	42.0 (105)	3.6 (9)	0.0 (0)	2.4 (6)	14.0 (35)	6.0 (15)
Hurling	20.0 (16)	12.5 (10)	35.0 (28)	3.8 (3)	1.3 (1)	0.0 (0)	20.0 (16)	7.5 (6)
Dual Gaelic football & Hurling	11.5 (9)	14.1 (11)	30.8 (24)	12.8 (10)	1.3 (1)	0.0 (0)	17.9 (14)	11.5 (9)
Ladies Gaelic football	12.7 (18)	4.9 (7)	16.9 (24)	10.6 (15)	0.0 (0)	0.0 (0)	23.2 (33)	31.7 (45)
Camogie	5.6 (4)	8.5 (6)	25.4 (18)	9.9 (7)	0.0 (0)	0.0 (0)	28.2 (20)	22.5 (16)
Dual Ladies Gaelic football & Camogie	13.8 (9)	7.7 (5)	27.7 (18)	7.7 (5)	0.0 (0)	0.0 (0)	24.6 (16)	18.5 (12)
Level of play								
Elite	40.3 (52)	16.3 (21)	24.8 (32)	1.6 (2)	0.0 (0)	1.6 (2)	10.1 (13)	5.4 (7)
Non-Elite	9.5 (53)	8.6 (48)	33.2 (184)	8.5 (47)	0.4 (2)	0.7 (4)	21.8 (121)	17.3 (96)

%: percentage; n: number.

5.4 Discussion

This study sought to understand the use and awareness of injury prevention exercise programmes in all codes of Gaelic games, their attitudes towards injury prevention and their use of other injury prevention practices. Almost a third of Gaelic games players stated that they were aware of a specific Gaelic games injury prevention exercise programme; however, only 42.5% of these correctly identified one. Thus, only 13.4% of all Gaelic games players are aware of and can name a specific injury prevention exercise programme. This is similar to previously reported in Camogie players (13.9%) (O'Connor et al., 2020), English schoolboy rugby players (13%) (Barden et al., 2021), and professional soccer players (9%) (O'Brien and Finch, 2017). Just under a third of Gaelic games players used an injury prevention exercise programme with their team. Although much higher than previously reported in Camogie (11.2%) (O'Connor et al., 2020), rugby (11%) (Barden et al., 2021), and soccer (2%) (O'Brien and Finch, 2017), the use of injury prevention exercise programmes remains low. The most popular injury prevention exercise programmes used in Gaelic games were the Activate GAA Warm-up and the GAA15. The GAA15 (2006) and the Activate GAA Warmup (2014) have existed for some time, but their adoption remains low. The GAA15 effectively reduces injuries when implemented (Kelly and Lodge, 2018; Schlingermann et al., 2018). Both the GAA 15 (Schlingermann et al., 2018; O'Malley et al., 2017) and the Activate GAA Warm-Up (O'Connor et al., 2022) have been shown to positively affect neuromuscular capacities, which may decrease the risk of injury. Despite both injury prevention exercise programmes being effective, most Gaelic games players are not adopting a specific injury prevention exercise programme for Gaelic games. The low use stated by players may be due to a lack of awareness amongst Gaelic games players, as they might not be aware that they are completing an injury prevention exercise programme. It has been argued that the coach is higher up the hierarchy for delivering injury prevention exercise programmes than the player (Emery et al., 2006). Organisations have primarily targeted coaches to implement injury prevention exercise programmes. Despite coaches' workshops and online resources, these actions typically do not produce favourable implementation (i.e., changes in behaviour) (Donaldson and Finch, 2013). However, it has previously been reported that only 7.7% of Gaelic football coaches (Reilly and Kipps, 2017) and 34% of Camogie coaches (O'Connor et al., 2020) are using a specific Gaelic games injury prevention exercise programme with their team. It is currently unknown if the use of injury prevention exercise programmes in Gaelic games has improved amongst coaches; therefore, further research is needed.

Implementation refers to the extent to which an intervention is implemented as intended in the real-world (Donaldson and Finch, 2013). While the Gaelic games-specific injury prevention exercise programmes are designed to be used before all training and matches, only half of the teams that use an injury prevention exercise programme do so at every training and match. Thus, programme fidelity is low, as only half implement an injury prevention exercise programme as directed. Injury prevention exercise programmes can only be successful if they are provided and used by participants in the manner they were designed (Finch and Donaldson, 2010). The present delivery techniques from an organisational level are insufficient at educating coaches on how to use injury prevention exercise programmes correctly with their team. When injury prevention exercise programmes are completed in Gaelic games, it is primarily the athletic development coach or the main coach that delivers the programme. However, further research is needed to investigate if and why coaches are not using injury prevention exercise programmes in Gaelic games as intended. Previously, it was found in youth soccer (Lindblom et al., 2014) and basketball (Norcross et al., 2016) that most coaches were not using injury prevention exercise programmes as intended. However, organisations must ensure that injury prevention exercise programmes are implemented as directed to get the intended benefit of using an injury prevention exercise programme.

Although the use of specific injury prevention exercise programmes was poor, they could incorporate injury prevention practices as part of their training or preparation. The injury prevention practices that Gaelic games players reported always using were warmups (74.7%) and stretching (53.8%). However, training elements such as landing (40.5%), balance training (35.5%) and training of proper sports technique (32.5%) are frequently never completed in training sessions. Previously it has been reported that stretching and warm-ups were the most popular elements of injury prevention that were always completed (McKay et al., 2014), similar to this study. Stretching was the training practice rated most effective by Gaelic games players. However, stretching has decreased injuries by only 4% (Lauersen et al., 2014). While fewer Gaelic games players always use (14.2%) and rated resistance training lower for preventing injuries, resistance training has been shown to decrease the risk of injury significantly (Lauersen et al., 2014). Thus, players should be educated on the best training practices to reduce the risk of injury so that time is spent practising those with the most significant benefit.

Good nutrition and adequate sleep were rated as the best interventions for injury prevention in Gaelic games. However, only one in every five players always practises adequate sleep (21.7%) and good nutrition (17.3%). Gaelic games players know what can aid recovery but only sometimes adhere to the practices. Although there is limited evidence to suggest that a lack of adequate sleep may increase the risk of injury (Dobrosielski et al., 2021), sleep is essential for players' best recovery and subsequent performance (Bonnar et al., 2018). Low-quality sleep has a detrimental effect on anaerobic power and cardiorespiratory endurance (Sadeh, 2011) and lowers maximum strength (Griffin et al., 2020), which may make it more difficult for an player to stay injury-free. Organisations should promote these good practices, which may be beneficial in optimising recovery.

Enhancing the adoption and implementation of injury prevention exercise programmes in actual community sports contexts is a complex process that needs support from many key stakeholder (Bekker and Clark, 2016). Understanding players' attitudes towards the intervention and how it fits within the framework of their everyday life and the culture of the sport are also crucial (Finch, 2006). Little evidence suggests that players were involved in the development process of Gaelic games injury prevention exercise programmes. However, this study indicates that Gaelic games players had a positive attitude towards injury prevention and agree that it is important that they have current knowledge of injury prevention exercise programmes. Gaelic games players agreed or strongly agreed (68.2%) that injuries were an issue with their team. This is similar to Camogie players' previous reports (69.5%) (O'Connor et al., 2020). Gaelic games players also believe that injuries can cause problems later in life (95.2%) and shorten a player's career (96.2%). Even though many Gaelic games players believe injury prevention exercise programmes are essential and beneficial and that injuries are a problem, very few implement an injury prevention exercise programme. Organisations and clubs should harness the positive attitude and target injury prevention exercise programmes and injury prevention information for players, which may increase the implementation of injury prevention exercise programmes. Further research is needed to investigate what formats of delivery of information on injury prevention exercise programmes players prefer to maximise engagement, such as injury prevention workshops or social media.

Evidence-based injury prevention exercise programmes must be used widely and with high fidelity to influence injury prevention significantly (Donaldson et al., 2017). Thus, it is essential to understand the barriers and facilitators in a Gaelic games context. There is evidence to suggest that Gaelic games players understand the benefits of injury prevention exercise programmes. However, the lack of adoption indicates that more research is required to put effective preventive approaches into practice to significantly decrease players' risk of injury (Verhagen et al., 2010). Thus, understanding and addressing the barriers and facilitators to injury prevention exercise programme implementation is critical. Gaelic games players lack confidence in their coaches' knowledge and skill on injury prevention exercise programme. Further research is needed to investigate coaches' awareness, knowledge, use and confidence in delivering an injury prevention exercise programme. Gaelic games players (83%) believed the introduction of a ball/hurley would be a facilitator to injury prevention exercise programmes. Prep to Play PRO, an Australian rules football injury prevention exercise programme has been well implemented partly due to its football-specific content, which has enhanced payer buy-in due to its focus on improving football performance (Bruder et al., 2021). While it is clear that players are aware of injuries and the benefits of injury prevention exercise programmes, this does not seem to motivate them to use them; therefore, making the injury prevention exercise programmes more sport specific or branding them as enhancing sports performance may increase the use of injury prevention exercise programmes amongst Gaelic games players. The Activate and the Camogie Injury Prevention Program include a ball/hurley, which may explain the relative popularity of the Activate. At an organisational level, reconsideration is needed to incorporate a ball/hurley into the GAA15 and make it more sport specific. Fewer injuries (90.7%) and more training on delivering injury prevention exercise programmes (83.5%) were the greatest facilitators of using injury prevention exercise programmes. Three in every four players agreed that observing an elite team would facilitate injury prevention exercise programme use. Having injury prevention exercise programmes endorsed by elite teams or players could increase implementation, as previously shown in the women’s AFL (Bruder et al., 2021). Although the implementation of injury prevention exercise programmes in Gaelic games is available to almost everyone and only takes a minimal amount of medical personnel help (Lauersen et al., 2014), Gaelic games players stated that having an athletic development coach (88.7%) or an Athletic Therapist/Physiotherapist (88.4%) deliver the injury prevention exercise programme would also help facilitate the implementation of injury prevention exercise programmes. The lack of confidence in coaches can partially explain this. The athletic development coach and medical staff should be more involved in delivering and implementing injury prevention exercise programmes since Gaelic games players trust their capacity to lead their team in an injury prevention exercise programme (Lindblom et al., 2014). However, under half of the Gaelic games players in this study had limited or no access to an athletic development coach, with elite and men players having greater access. Over half (51.1%) of women's Gaelic games players occasionally or never have access to medical personnel. This contrasts with men's Gaelic games players, with less than 1 in four (23%) occasionally or never having access to medical personnel. These significant discrepancies may be due to the discrepancies in funding between men's and women's sports (Kelly et al., 2022). More funding should be made available to teams, particularly women's teams, to priories frequent access to athletic development coaches and medical personnel.

Limitations

The survey's Likert scale questions may have been subject to central tendency bias, acquiescence bias, or social desirability bias, which might have affected participants' responses. A convenience sampling strategy was used, and respondents to this survey elected to complete it on a self-selected basis which may have led to those more interested in injury prevention being more likely to complete this study. Similarly, the sample size may not be generalizable to all Gaelic Games players and it is unknown how many player actually received the survey. Injury history, among other potential confounding factors, might have altered respondents' impressions but were not queried in this study. The study did not examine the objective of receiving additional education regarding injury prevention exercise programmes due to survey length restrictions. Still, it should be included in subsequent studies of a similar nature. Further qualitative research may help gain a more in-depth understanding of end-user attitudes and contextual difficulties in implementing injury prevention exercise programme.

5.5 Conclusion

Previously injury prevention exercise programmes were found effective in reducing injury and increasing neuromuscular performance. However, implementing an intervention requires more than just an effective programme. This study identified that the adoption of injury prevention exercise programmes in Gaelic games is low. Despite Gaelic games players believing that injuries are an issue with their team, they lack awareness of injury prevention exercise programmes. However, Gaelic games players have a positive attitude towards injury prevention and want current knowledge of injury prevention exercise programmes. Therefore, there is an opportunity for organisations and clubs to educate players on the benefits of using injury prevention exercise programmes and thus gain greater awareness and implementation of injury prevention exercise programmes, which is critical to mitigating the risk of injury in Gaelic games. Organisations should address some of the barriers to the use of injury prevention exercise programmes identified by players, such as no ball/hurley involved and teams needing someone with adequate knowledge and skill to deliver injury prevention exercise programmes. They should comply with some of the facilitators, such as better resources, more training available for players and making funding available for equal access to coaching staff and medical personnel across all codes. More frequent access to these may also facilitate the use of injury prevention exercise programmes in Gaelic games players.

Link to Chapter 6

From Chapter 5, it was found that greater than four in every five players believe that Gaelic games players are at a high risk of injury, and two in every three believe that injuries are an issue with their team. However, Gaelic games players have a positive attitude towards injury prevention exercise programmes, with 95.7% believing that they are important to use during sessions and 91.4% believing that they will reduce the number of injuries in their team. Despite this, less than a third of players knew that injury prevention exercise programmes exist. Of these, only 41% could correctly name a Gaelic games-specific injury prevention exercise programme. Overall 31.7% of Gaelic games players stated that they used an injury prevention exercise programme with their team, with significantly fewer female players stating they used a programme. This is relatively low considering that players have a positive attitude to injury prevention and believe that injuries are an issue. However, almost three in every ten players were unsure if they used an injury prevention exercise programme with their team. This is not surprising as players are the end users of the programmes, however implementation of such programmes is the coach's responsibility. Two in every five players stated that their coach didn’t know how to use injury prevention exercise programmes and a third believe that their team doesn’t have anyone with the adequate skill to lead them in a programme. However, coaches are another key stakeholder and particularly in community level they have the responsibility of implementing an injury prevention exercise programme. Therefore, coaches' awareness of, use, and attitudes towards injury prevention exercise programmes must be examined as well as their confidence in delivering an intervention.

Chapter 6 Study 4 - Gaelic Games Coaches’ Attitudes Towards, Awareness of and Use of Injury Prevention Exercise Programmes

6.1 Introduction

Gaelic Games are sports native to Ireland, including Gaelic football, hurling, Ladies Gaelic football, and Camogie. Gaelic games are governed by the Gaelic Athletic Association (GAA), Ladies Gaelic Football Association (LGFA), and Camogie Association, respectively. The competition spans from regional clubs (at a community level) to national inter-county events (at the elite level) (O'Connor et al., 2020). Gaelic games are amateur sports, with the vast majority of coaches being volunteers (95.2%) (Horgan et al., 2021). Coaching commitments can be high. More than 3 in 4 Gaelic games coaches deliver at least 2-3 sessions a week (Horgan et al., 2021). It is also common for coaches (2 in every 5) to coach more than one code (one of Gaelic football, Ladies Gaelic football, hurling or Camogie) or team or level at any one time (Horgan et al., 2021). Sports participation comes with the inherent risk of injury (Melzer et al., 2004). Lower extremity injuries are the most common across all codes of Gaelic games, although injury rates vary depending on the sport and level; however, match injury rates are significant in all codes (26.4-102.5 injuries/1000 hours) (Murphy et al., 2012; Buckley and Blake, 2018; O'Connor et al., 2021; Murphy et al., 2010). Sports-related injuries are expensive (Al Attar and Alshehri, 2019), and have a substantial financial burden on the player and club. Successfully implementing widespread injury prevention practices across all Gaelic games players is crucial due to the current prevalence of injuries and the need to reduce costs for the individual player, team and society (Mendonça et al., 2021; Sly et al., 2022). The coach is critical for providing safety interventions to players and is primarily responsible for injury prevention implementation (Donaldson et al., 2017), particularly to underage players (White et al., 2014), and community-level sports (Finch and Donaldson, 2010), where coaching and medical staff are lacking (Arundale et al., 2022), such as Gaelic games.

One strategy for minimising team sports injury rates is using injury prevention exercise programmes (Sly et al., 2022). Greater implementation activity results from delivering programme material underpinned by a context-specific and evidence-based implementation strategy such as the TRIPP model, which is crucial for injury reduction (Benjaminse and Verhagen, 2021). Several Gaelic games-specific injury prevention exercise programmes have been developed including the GAA15 (GAA.ie), the Activate GAA Warm-up (Ulster.GAA.ie), the Camogie Injury Prevention Programme (CIPP)

(Camogie.ie), and The Athletic Development and Injury Prevention Program (Ladiesgaelic.ie). Only three studies have looked at the effectiveness of the GAA15 and indicated that it increased neuromuscular performance (O'Malley et al., 2017; Schlingermann et al., 2018), and decreased the incidence of lower limb injuries in collegiate Gaelic games players (Schlingermann et al., 2018), and adolescent hurlers (Kelly and Lodge, 2018). The Activate GAA Warm-up has also been shown to enhance neuromuscular function, which could mitigate some risk factors for injury (O'Connor et al., 2022). While this suggests that the GAA15 and the Activate GAA Warm-up both are effective, only injury prevention exercise programmes that coaches are aware of and use will be effective at tangibly reducing injury (Donaldson et al., 2017; O'Brien et al., 2016; Stensø et al., 2022). Although more research is needed on coaches' awareness of and usage of injury prevention exercise programmes in Gaelic games, the available research demonstrates that the awareness (32%) and use (34%) of injury prevention exercise programmes were low amongst Camogie coaches (O'Connor et al., 2020), and Gaelic football coaches (7.7%) (Reilly and Kipps, 2017). There has yet to be any previous research investigating the awareness of and use of injury prevention exercise programmes amongst coaches coaching different genders in Gaelic games. This is important to understand as coaches coaching female high school players had greater awareness and use of injury prevention exercise programmes than coaches coaching boys (Perera and Hägglund, 2020), and the various organisations governing the Gaelic games codes have different coach education pathways, which may need to be targeted in the future. injury prevention exercise programmes can only be effective at reducing injuries if stakeholders apply them in the way that they were intended (Finch and Donaldson, 2010; McGlashan et al., 2018). Therefore, it is critical to understand the awareness of and use of injury prevention exercise programmes by Gaelic games coaches.

It is essential to understand Gaelic games coaches' attitudes to injury and injury prevention and the barriers and facilitators to successful implementation to increase the effectiveness of use, fidelity and maintaining injury prevention exercise programmes over time (Donaldson et al., 2017; McGlashan et al., 2018). Even though players are these programmes' intended end users, coaches' attitudes affect whether or not players receive these training programmes in the first place (Finch et al., 2014; White et al., 2014). Understanding and removing any barriers to implementing injury prevention exercise programme can assist them in succeeding further, particularly in community-based sports

(White et al., 2014). Future developments in injury prevention are likely to occur with an improved understanding of how to use evidence-based strategies in the real world (Benjaminse and Verhagen, 2021). Only one study has looked at the attitudes of coaches, barriers and facilitators to injury prevention exercise programme use and coaches' perceived ability to implement an injury prevention exercise programme in Camogie (O'Connor et al., 2020), hence, more research is needed across all codes of Gaelic games. Therefore, this study aimed to determine the awareness of, use of injury prevention exercise programmes and attitudes towards injury prevention exercise programmes among Gaelic games coaches and if differences exist between the gender of the coach, levels of play, the gender of the team they coach and between coaches who had completed a Gaelic games specific coaching course. This study also aimed to identify perceived barriers and facilitators to injury prevention exercise programme use in Gaelic games, and examine the perceived ability of coaches to deliver injury prevention exercise programmes.

6.2 Methods

6.2.1 Participants and study design

An anonymous online cross-sectional survey was implemented. Dublin City University's Research Ethics Committee (DCUREC/2021/137) granted ethical approval prior to data collection. Participants currently coaching Gaelic football, Ladies Gaelic football, hurling, or Camogie and were 18 years of age and older were eligible to complete the survey. Participants first read a plain language statement and gave their informed consent before completing the survey, which took an average of 17.2±7.0 minutes.

6.2.2 Instrumentation

The anonymous survey was modified from prior studies to the Gaelic games context (O'Connor et al., 2020; Finch, 2002; Fokkema et al., 2019; Martinez et al., 2017; McKay et al., 2014; Møller et al., 2021; Wilke et al., 2018; Zech and Wellmann, 2017), and was validated through a review process by academics, specialising in the domains of coaching (n = 2), sport science (n = 2), and injury prevention (n = 3). Each question was evaluated for clarity, comprehensiveness, and appropriateness and assigned a score between 1 and 5. Questions that had less than a 4/5 average were modified or removed

(Mawson et al., 2018). Finally, seven coaches from all four Gaelic games codes participated in the survey piloting.

Eight demographic questions were included in Section 1. The coach's gender, age, the sport they coached, the number of years of coaching experience, coaching education, and the location of their club were all queried. Section 2 consisted of five questions which examined preseason screening with their team and access to coaches and medical personnel (O'Connor et al., 2020; Wilke et al., 2018). Section 3 consisted of nine questions investigating coaches' awareness of Gaelic games injury prevention exercise programmes, and use of injury prevention exercise programmes and gathered information on how frequently, by whom, and for how long per session they were delivered (O'Connor et al., 2020; McKay et al., 2014). If coaches did not use injury prevention exercise programmes, this section also investigated the reasons for this. Section 4 (3 questions) assessed how coaches perceived various injury prevention practices and how frequently they employed them (Fokkema et al., 2019; Martinez et al., 2017; Wilke et al., 2018; Zech and Wellmann, 2017). Section 5 (3 questions) examined coaches' levels of agreement on their attitudes toward safety behaviours and perceived behavioural control factors relating to the amount of support a player received or anticipated to be received if the player had been injured or were to be injured, as well as their attitudes towards injury and injury prevention (21 statements) (O'Connor et al., 2020; Møller et al., 2021; Martinez et al., 2017; Finch, 2002). Section 6, composed of two questions, looked at the facilitators and barriers to effective injury prevention use (17 statements total) (O'Connor et al., 2020). A 5-point Likert scale ranged from "strongly disagree" to "strongly agree". The final section consisted of one question on the coaches' perceived ability to conduct an injury prevention exercise programme (4 statements). A 5-point Likert scale ranged from "extremely not confident" to "extremely confident".

6.2.3 Procedures

Using the online calculator provided by Qualtrics (SAP America Inc., Seattle, WA), the sample size was calculated and found to be 270. An estimated population size of 50,000, a confidence level of 90% and a margin of error of 5% were used. Every county board secretary (n=104) and club secretary (n=2157) in Ireland received a recruiting email with details and a survey link. The distribution of the survey to all adult coaches was requested. A reminder email was sent three and six weeks after the original email. Social media and word of mouth were used to publicise and distribute the survey. The survey was hosted online on Qualtrics (SAP America Inc., Seattle, WA) and was available from May 13 through July 15, 2022.

6.2.4 Data analysis

Responses were exported to SPSS Statistics (version 27, IBM Corporation). Data were checked for errors or missing information. In cases where at least 80% of the survey wasn't filled out, data were excluded from the analysis. From the valid replies, frequencies and descriptive statistics were produced.

The data were not normally distributed. A chi-squared test evaluated differences between the gender of the coach, levels of play, the gender of the team that they coach and between coaches who had completed a Gaelic games-specific coaching course in the use and awareness of injury prevention exercise programmes and if their team had access to athletic development coaches (strength and conditioning, fitness coach etc.) and medical staff (athletic therapist, physiotherapist, physical therapist etc.). Classification of effect sizes (phi) was small (0.1), medium (0.3), and large (0.5). Statistical significance was set a priori at 0.05. An attitude towards injury prevention scale was created by assigning a score ranging from 1 to all "strongly disagree" replies to a value of 5 to all "strongly agree". Negative phrases were inverted to ensure that a higher score on the scale corresponds to a more optimistic outlook towards injury prevention. Similarly, a scale of attitudes toward injury was developed from 7 statements. Adequate internal consistency was observed for the attitudes towards injury scale (inter-item correlation=0.2) and attitudes toward injury prevention (Cronbach's alpha=0.75). Mann-Whitney U tests were used to determine statistically significant differences between the gender of the coach, levels of play and between coaches who had completed a Gaelic games-specific coaching course for attitudes toward injury and injury prevention. Classifications of effect sizes were small (0.1), medium (0.3), and large (0.5). Statistical significance was set a priori at 0.05.

6.3 Results

A total of 698 coaches accessed the questionnaire, but 356 responses were insufficient as less than 80% of the questionnaire was completed. Therefore, a total of

342 responses (254 men, 87 women and 1 non-binary/third gender) met the inclusion criteria and were included in the analysis. Coaches had a mean age of 48.6±9.2 years and 11.7±9.1 years of coaching experience. Coaches were predominantly non-elite (90.6%), and only 34.5% (n=118) had completed a Gaelic games-specific coaching course. The breakdown of the respondents' Gaelic games code they coached is presented in Table 6.1.

Table 6. 1. Total number and percentage of coaches that coach in each Gaelic Games code.

Gaelic games code	**Total % (n) (n=342)**	**Elite % (n) (n=32)**	**Non-elite % (n) (n=309)**
Total	-	9.4 (32)	90.6 (309)
Men's Gaelic football only	26.0 (89)	18.8 (6)	26.5 (82)
Hurling only	8.5 (29)	9.4 (3)	8.4 (26)
Ladies Gaelic football only	20.5 (70)	12.5 (4)	21.4 (66)
Camogie	8.8 (30)	9.4 (3)	8.7 (27)
Gaelic football (both men and women)	11.4 (39)	15.6 (5)	11.0 (34)
Hurling and Camogie	4.4 (15)	12.5 (4)	3.6 (11)
Gaelic football and Hurling	16.1 (55)	18.8 (6)	15.9 (49)
Ladies Gaelic football and Camogie	4.4 (15)	3.1 (1)	4.5 (14)

%: percentage; n: sample size.

6.3.1 Awareness and Use of Injury Prevention Exercise Programmes

Just under half of all coaches (44.1%) were aware of an injury prevention exercise programme. Almost half of men Gaelic games coaches (47.9%) (Table 6.2) stated that they were aware of a specific Gaelic games injury prevention exercise programme, with statistically fewer women Gaelic games coaches aware (31.1%) with small effect size (p<0.01, *phi*=0.25). Similarly, there was a difference between the gender coaches coached and awareness (p=0.03, phi=0.16).

There was no significant difference in awareness of injury prevention exercise programmes for coaches coaching at different levels of play (p=0.08, *phi*=0.12) and between coaches with or without formal Gaelic games coaching education (p=0.19, *phi*=0.08). Of the coaches that stated their awareness of a specific Gaelic games injury prevention exercise programme, 70.0% correctly identified one. The GAA15 (76.8%) and the Activate GAA warm-up (17.9%) were the injury prevention exercise programmes that coaches were predominantly aware of.

Table 6. 2. Gaelic Games Coaches Awareness of, and Use of an Injury Prevention Exercise Programme and the Type utilised.

Sport/Gender	Awareness of an IPEP % (n)	Use of an IPEP % (n)	Injury prevention exercise programme used. % (n)						
			GAA 15	Activate GAA Warm-up	Camogie Injury Prevention Programme	The Athletic Development and Injury Prevention Warm Up	Modified Injury prevention Exercise Programme	One I developed myself	Other
Total	44.1 (130)	59.5 (165)	25.9 (36)	37.4 (52)	3.6 (5)	5.0 (7)	7.2 (10)	12.2 (17)	8.6 (12)
Gender of the coach									
Men coaches	47.9 (109)	62.3 (139)	27.9 (31)	38.7 (43)	0.9 (1)	4.5 (5)	7.2 (8)	12.6 (14)	8.1 (9)
Women coaches	31.3 (21)	50.0 (33)	17.9 (5)	32.1 (9)	14.3 (4)	7.1 (2)	7.1 (2)	10.7 (3)	10.7 (3)
Level of play									
Elite	62.1 (18)	71.9 (23)	18.2 (2)	18.2 (2)	0.0 (0)	9.1 (1)	9.1 (1)	27.3 (3)	18.2 (2)
Non-elite	41.9 (111)	57.1 (148)	26.6 (34)	39.1 (50)	3.9 (5)	4.7 (6)	7.0 (9)	10.9 (14)	7.8 (10)
Gaelic games coaching course completed									
Yes	38.8 (40)	53.9 (55)	35.8 (19)	41.5 (22)	0.0 (0)	5.7 (3)	5.7 (3)	5.7 (3)	5.7 (3)
No	46.9 (90)	62.6 (117)	19.8 (17)	34.9 (30)	5.8 (5)	4.7 (4)	8.1 (7)	16.3 (14)	10.5 (9)
Gender of the sport they are Coaching									
Coaching men	48.7 (74)	61.3 (92)	32.1 (25)	41.0 (32)	0.0 (0)	6.4 (5)	7.7 (6)	7.7 (6)	5.1 (4)
Coaching women	33.3 (33)	54.6 (53)	11.4 (5)	38.6 (17)	9.1 (4)	4.5 (2)	6.8 (3)	20.5 (9)	9.1 (4)

Coaching both men and women	52.3 (23)	64.3 (27)	35.3 (6)	17.6 (3)	5.9 (1)	0.0 (0)	5.9 (1)	11.8 (2)	23.5 (4)
				Gaelic games code					
Mens Gaelic football	51.9 (40)	67.5 (52)	36.4 (16)	28.6 (17)	0.0 (0)	9.1 (4)	9.1 (4)	6.8 (3)	0.0 (0)
Hurling	24.0 (6)	54.2 (13)	20.0 (2)	50.0 (5)	0.0 (0)	0.0 (0)	10.0 (1)	10.0 (1)	10.0 (1)
Ladies Gaelic football	38.1 (24)	58.1 (36)	9.7 (3)	41.9 (13)	0.0 (0)	6.5 (2)	6.5 (2)	22.6 (7)	12.9 (4)
Camogie	16.6 (4)	39.1 (9)	22.2 (2)	33.3 (3)	22.2 (2)	0.0 (0)	11.1 (1)	11.1 (1)	0.0 (0)
Gaelic football (both men and women)	53.3 (16)	67.9 (19)	33.3 (4)	25.0 (3)	0.0 (0)	0.0 (0)	0.0 (0)	16.7 (2)	25.0 (3)
Hurling and Camogie	50.0 (7)	57.1 (8)	40.0 (2)	0.0 (0)	20.0 (1)	0.0 (0)	20.0 (1)	0.0 (0)	20.0 (1)
Gaelic football and Hurling	54.9 (28)	56.0 (28)	28.0 (7)	44.0 (11)	0.0 (0)	4.0 (1)	4.0 (1)	8.0 (2)	12.0 (3)
Ladies Gaelic football and Camogie	45.5 (5)	63.6 (7)	0.0 (0)	0.0 (0)	66.7 (2)	0.0 (0)	0.0 (0)	33.3 (1)	0.0 (0)

IPEP: injury prevention exercise programme; %: percentage; n: number.

In total, 59.5% of coaches used injury prevention exercise programmes. Elite coaches (71.9%) had significantly higher use of injury prevention exercise programmes compared with non-elite (57.1%) with a small effect size ($p<0.01$, phi=0.16). However, there was no significant difference in the use of injury prevention exercise programmes for the gender of the coach ($p=0.20$, phi=0.11) between coaches who have or have not completed a Gaelic games coaching course ($p=0.33$, phi=0.09) and the gender of sport that they coach ($p=0.79$, phi=0.08). For the coaches that use an injury prevention exercise programme, the most frequently used injury prevention exercise programmes across all codes were the Activate GAA Warm-up (37.4%) and the GAA 15 (25.9%). Almost 1 in every 5 coaches has either developed their own injury prevention exercise programme (12.2%) or has modified an injury prevention exercise programme (7.2%). Injury prevention exercise programmes are completed mostly at every training (45.7%) and every training and match (35.8%) (Table 6.3). Two in every five coaches (39.9%) spent between 11 and 15 minutes delivering injury prevention exercise programmes with their team. For the coaches not using an injury prevention exercise programme, the most frequent reason was because of lack of skill set (20.6%), lack of resources (19.0%) and lack of time/too long or coaching underage (both 15.9%) (Table 6.3).

6.3.2 Injury prevention practice

Most coaches used a warm-up (89.0%) with their team most of the time or always, along with stretching (80.5%) and a cool-down (69.4%) (Table 6.4). Injury prevention practices such as landing technique (59.3%), resistance training (50.8%) and plyometrics (42.5%) were largely only sometimes or never completed. Coaches rated stretching, adequate sleep, and good nutrition as the most effective injury prevention practice.

Table 6. 3. Delivery, Frequency, and Duration of Injury Prevention Exercise Programmes in Gaelic Games and reasons for not using one.

Who is responsible for the delivery of an injury prevention exercise programme with your team (n=84) - % (n)	
Coach (me)	44.0 (37)
Coach (other)	31.0 (26)
Athletic Development Coach	16.7 (14)
Medical personnel	2.4 (2)
Player led	4.8 (4)
Self-administered outside of training	1.2 (1)
How often are injury prevention exercise programmes carried out by your team (n=162) - % (n)	
Every training	45.7 (74)
Every match	1.2 (2)
Every training and match	35.8 (58)
One training a week	7.4 (12)
Less than one training/match a week	5.6 (9)
Completed outside of training and match time	4.3 (7)
How long does your team spend implementing injury prevention exercise programme (n=168) - % (n)	
None	1.8 (3)
1 to 5 mins	10.7 (18)
6 to 10 mins	31.5 (53)
11 to 15 mins	39.9 (67)
16 to 20 mins	10.7 (18)
> 20 mins	5.4 (9)
Why do you not use an injury prevention exercise programme with your team (n=63) - % (n)	
Lack of skill set to use an IPEP	20.6 (13)
Lack of resources	19.0 (12)
Coaching an underage team	15.9 (10)
Lack of time in sessions/IPEPs are too long	15.9 (10)

Never knew that they existed	7.9 (5)
Lack of confidence using an IPEP	4.8 (3)
IPEPs are too boring/repetitive	4.8 (3)
Lack of equipment	3.2 (2)
I use my own	4.8 (3)
Never thought about using one	1.6 (1)
IPEPs are poorly sequenced	1.6 (1)

%: percentage; n: number; IPEP: injury prevention exercise programme.

Table 6. 4. Injury Prevention Practice Usage and Coaches' Rating of the Effectiveness of the Practice for Prevention of Injury in Gaelic games.

	Which injury prevention practices are used with your team					**How effective do you rate the following practices for injury prevention**				
	Never % (n)	**Sometimes** % (n)	**About half the time** % (n)	**Most of the time** % (n)	**Always** % (n)	**Total**	**Elite**	**Non-elite**	**Men**	**Women**
Activation	29.0 (83)	24.1 (69)	8.4 (24)	21.3 (61)	17.1 (49)	6.6±2.0	6.7±2.4	6.6±2.0	6.6±2.0	6.6±2.2
Active Recovery	14.1 (38)	23.0 (62)	13.4 (36)	31.2 (84)	18.2 (49)	7.4±1.8	8.0±2.2	7.4±1.8	7.3±1.8	7.8±1.9
Adequate sleep	16.8 (47)	18.9 (53)	11.8 (33)	29.6 (83)	22.9 (64)	8.1±1.9	8.9±1.4	8.0±2.0	8.0±1.9	8.1±2.1
Agility	4.0 (11)	24.3 (67)	19.6 (54)	34.4 (95)	17.8 (49)	7.8±1.8	7.8±2.0	7.8±1.7	7.7±1.7	8.1±1.8
Balance	15.3 (42)	57.7 (116)	20.8 (57)	15.7 (43)	5.8 (16)	7.0±2.4	6.3±2.3	7.0±2.0	6.7±2.0	7.2±2.1
Compression garments	67.4 (186)	23.2 (64)	4.7 (13)	2.5 (7)	2.2 (6)	4.3±2.0	4.0±2.4	4.3±2.0	4.3±2.0	4.3±1.9
Cool down	4.3 (12)	16.5 (46)	9.7 (27)	19.4 (54)	50.0 (139)	7.0±2.4	6.6±2.7	7.0±2.4	6.7±2.4	7.8±2.4
Core stability	8.7 (24)	26.2 (72)	27.6 (76)	27.6 (76)	9.8 (27)	7.8±1.9	7.9±1.4	7.8±1.9	7.6±1.9	8.4±1.5
Cryotherapy	69.3 (192)	23.5 (65)	5.1 (14)	1.4 (4)	0.7 (2)	4.7±2.4	4.8±2.6	4.6±2.4	4.7±2.5	4.5±2.3
Education	31.4 (87)	38.6 (107)	13.4 (37)	10.5 (29)	6.1 (17)	7.1±2.5	8.0±2.1	7.0±2.5	7.0±2.5	7.5±2.5
Endurance	11.6 (32)	35.6 (98)	21.1 (58)	22.9 (63)	8.7 (24)	6.3±2.1	7.5±2.0	6.2±2.1	6.3±2.1	6.4±2.2
Foam rolling	30.1 (103)	35.0 (97)	7.6 (21)	10.1 (28)	10.1 (28)	6.0±2.5	6.3±2.3	6.0±2.5	5.9±2.5	6.5±2.5
Good nutrition	12.2 (34)	23.7 (66)	16.2 (45)	24.8 (69)	18.7 (64)	8.2±1.8	9.1±1.1	8.1±1.9	8.2±1.9	8.5±1.7
Knowledge of the rules	11.50 (21)	21.9 (61)	19.1 (53)	30.2 (84)	17.3 (48)	6.3±2.8	6.6±2.9	6.3±2.8	5.9±2.7	7.8±2.7
Load management	15.2 (41)	17.3 (48)	22.4 (62)	23.8 (66)	21.3 (59)	8.0±1.8	8.7±1.8	7.9±1.8	8.1±1.8	7.5±2.0
Massage	50.7 (141)	30.9 (86)	6.8 (19)	8.6 (24)	2.9 (8)	5.7±2.2	5.9±2.7	5.6±2.1	5.5±2.1	6.1±2.4
Orthoses	64.7 (178)	26.5 (73)	4.7 (13)	2.2 (6)	1.8 (5)	5.1±2.5	4.7±2.2	5.1±2.5	5.1±2.5	5.1±2.4

Plyometrics	12.5 (34)	30.0 (82)	27.1 (74)	17.2 (47)	13.2 (36)	7.3±1.9	7.7±1.8	7.3±1.9	7.2±1.9	7.6±1.9
Recovery boots	76.6 (210)	16.4 (45)	4.7 (13)	1.5 (4)	0.7 (2)	4.3±2.4	4.7±2.7	4.3±2.3	4.3±2.3	4.4±2.5
Resistance training	17.8 (49)	33.0 (91)	18.1 (50)	21.4 (59)	9.8 (27)	7.0±2.0	8.2±1.8	6.9±2.0	7.0±2.0	5.1±2.1
Speed training	4.0 (11)	21.7 (60)	23.1 (64)	33.9 (94)	17.3 (48)	7.3±2.0	8.4±1.6	7.2±1.9	7.3±2.0	7.2±2.1
Stretching	2.9 (8)	10.8 (30)	5.8 (16)	22.0 (61)	58.5 (162)	8.2±2.0	7.8±2.3	8.3±2.0	8.0±2.1	9.0±1.6
Taping	32.6 (89)	39.6 (108)	12.8 (35)	9.5 (26)	5.5 (15)	5.2±2.3	5.1±2.7	5.2±2.3	5.1±2.3	5.7±2.5
Training of functional movements	14.9 (41)	30.9 (85)	27.3 (75)	18.2 (50)	8.7 (24)	7.6±2.0	8.0±1.9	7.5±2.0	7.6±1.9	7.5±2.4
Landing technique	22.9 (63)	36.4 (100)	21.8 (60)	11.3 (31)	7.6 (21)	7.3±2.0	7.6±1.8	7.3±2.0	7.2±1.9	7.6±2.2
Proper sports technique	11.7 (32)	19.0 (52)	21.9 (60)	25.9 (71)	21.5 (59)	7.7±1.9	7.9±1.9	7.7±1.9	7.6±1.8	8.0±2.2
Warmup	0.4 (1)	5.9 (16)	4.8 (13)	16.5 (45)	72.5 (198)	8.0±2.0	7.7±2.0	8.0±2.0	7.7±1.9	8.9±1.7

%: percentage; n: number.

6.3.3 Attitudes to injury and injury prevention and Barriers and Facilitators

Over 9 in every 10 coaches believe that injuries can shorten a player's career (93.1%) and that injuries cause problems later in life (94.2%) (Table 6.5). Three in every four believe that Gaelic games players are at high risk of injury, but less than two in every 5 believe that injuries are an issue with their team (36.2%). Women coaches had a significantly greater negative attitude to injury (median = 19), compared to men (median = 18), with a medium effect size (r=0.43, *p*=0.01). There were no significant differences in attitudes towards injury for the level of play (r=0.03, *p*=0.47), between coaches who have completed a Gaelic games coaching course (r=0.05, *p*=0.35) and the gender of sport that they coach (r=0.27, *p*=0.12).

Gaelic games coaches believe that it is important for both coaches (95.7%) and players (96.9%) to have current knowledge of injury prevention exercise programmes. Nine in every ten coaches (91.5%) believe that using an injury prevention exercise programme will reduce the number of injuries to their team. There were no significant differences in attitudes towards injury for the gender of the coach (r=0.14, *p*=0.13), the level of play (r=0.07, *p*=0.29) between coaches who have completed a Gaelic games coaching course (r=0.18, *p*=0.09) and the gender of sport that they coach (r=0.13, *p*=0.34). More training in delivering injury prevention exercise programmes (85.2%) and better resources (84.9%) were the greatest facilitators of using injury prevention exercise programmes. Four in every ten coaches stated that they did not have enough knowledge on how to use injury prevention exercise programmes (40.6%), while 34.5% believed that there was no training available to teach them (Table 6.5).

Table 6. 5. Coaches' Attitudes Towards Injury and Injury Prevention Exercise Programmes and Barriers and Facilitators to their Successful Use.

	Strongly disagree % (n)	**Disagree** % (n)	**Neither agree or disagree** % (n)	**Agree** % (n)	**Strongly agree** % (n)
Negative statements to injury and injury prevention					
Injuries are an issue with my team (n=260)	9.6 (25)	25.8 (67)	28.5 (74)	28.5 (74)	7.7 (20)
Injuries can shorten a player's career (n=258)	3.9 (10)	1.2 (3)	1.9 (5)	32.6 (84)	60.5 (156)
Injuries can cause physical problems later in life (n=259)	2.7 (7)	0.0 (0)	3.1 (8)	41.3 (107)	52.9 (137)
Injuries have a negative impact on team performance (n=257)	1.6 (4)	1.6 (4)	9.3 (24)	40.1 (103)	47.5 (122)
Gaelic games players are at a high risk of suffering an injury (n=260)	2.3 (6)	1.5 (4)	21.9 (57)	46.9 (122)	27.3 (71)
IPEPs cost too much (n=259)	16.2 (42)	27.0 (70)	42.9 (111)	12.7 (33)	1.2 (3)
IPEPs takes up too much training time away from necessary tasks (n=260)	21.5 (56)	42.7 (111)	28.5 (74)	6.5 (17)	0.8 (2)
Positive statements to injury and injury prevention					
It's important for coaches to have current knowledge of IPEPs (n=259)	1.5 (4)	0.8 (2)	1.9 (5)	47.1 (122)	48.6 (126)
It's important for players to have current knowledge of IPEPs (n=259)	1.5 (4)	0.0 (0)	1.5 (4)	51.7 (134)	45.2 (117)
Injury prevention is important during training sessions (n=258)	0.8 (2)	0.8 (2)	3.1 (8)	52.3 (135)	43.0 (111)
Activities included in IPEPs are relevant and beneficial to players (n=259)	0.8 (2)	0.4 (1)	4.6 (12)	51.4 (133)	42.9 (111)
I believe that using an IPEP will reduce the number of injuries for my team (n=258)	0.8 (2)	0.4 (1)	7.4 (19)	50.4 (130)	41.1 (106)

I believe that injuries are preventable (n=258)	1.9 (5)	8.9 (23)	25.2 (65)	47.7 (123)	16.3 (42)
Exercises which have been shown to prevent injuries should be performed by Gaelic games players (n=259)	0.0 (0)	0.0 (0)	4.2 (11)	51.7 (134)	44.0 (114)
Exercises to prevent injuries should be varied and progressed over time (n=258)	0.0 (0)	0.0 (0)	7.4 (19)	60.1 (155)	32.6 (84)
Attitudes on Safety Behaviours					
I believe that it is safe to play with injuries (n=259)	41.3 (107)	41.7 (108)	11.6 (30)	3.1 (8)	2.3 (6)
I am willing to let my players play with injuries (n=260)	45.0 (117)	35.8 (93)	11.2 (29)	6.9 (18)	1.2 (3)
I admire Gaelic games players who continue to play when injured (n=259)	37.8 (98)	39.8 (103)	15.4 (40)	5.4 (14)	1.5 (4)
Perceived behavioural control factors relating to the level of support received, or expected to be received, if the player had been injured or were to be injured					
I believe that players should be fully rehabilitated before playing again after they have suffered an injury (n=259)	5.4 (14)	6.2 (16)	11.2 (29)	35.5 (92)	41.7 (108)
I support players when they are injured (n=259)	2.3 (6)	1.5 (4)	3.1 (8)	51.4 (133)	41.7 (108)
The club assist players with medical issues (n=260)	5.0 (13)	6.5 (17)	17.7 (46)	45.8 (119)	25.0 (65)
Facilitators to injury prevention exercise programme use					
Observing elite teams (n=237)	1.7 (4)	3.8 (9)	14.8 (35)	56.1 (133)	23.6 (56)
Better resources (n=238)	1.7 (4)	3.4 (8)	10.1 (24)	57.6 (137)	27.3 (65)
More training in the delivery (n=237)	1.7 (4)	1.7 (4)	11.4 (27)	58.2 (138)	27.0 (64)
The introduction of a ball or skills (n=236)	1.3 (3)	4.7 (11)	12.7 (30)	52.5 (124)	28.8 (68)
A player in my team having a serious injury (n=234)	3.4 (8)	11.5 (27)	21.4 (50)	48.3 (113)	15.4 (36)
A player would run faster (n=235)	5.5 (13)	12.3 (29)	27.2 (64)	40.0 (94)	14.9 (35)

A player would jump higher (n=234)	6.4 (15)	16.2 (38)	28.6 (67)	35.0 (82)	13.7 (32)
A player would have fewer risk factors for injury (n=235)	2.1 (5)	3.4 (8)	10.6 (25)	51.5 (121)	32.3 (76)
I would feel comfortable leading IPEP (n=234)	2.1 (5)	13.2 (31)	17.1 (40)	40.2 (94)	27.4 (64)
I would feel comfortable with a player leading IPEP (n=234)	3.0 (7)	13.2 (31)	16.7 (39)	52.6 (123)	14.5 (34)
I would feel comfortable with another coach leading IPEP (n=233)	1.3 (3)	5.2 (12)	12.4 (29)	52.8 (123)	28.3 (66)
I would feel comfortable with my athletic development coach leading IPEP (n=234)	0.0 (0)	1.3 (3)	7.3 (17)	46.2 (108)	45.3 (106)
I would feel comfortable with my AT/Physio Leading IPEP (n=231)	0.0 (0)	1.3 (3)	11.3 (26)	48.5 (112)	39.0 (90)
Barriers to injury prevention exercise programme use					
My teams training sessions are not long enough (n=249)	14.5 (36)	41.0 (102)	22.5 (56)	18.5 (46)	3.6 (9)
IPEP is too long (n=248)	13.3 (33)	35.9 (89)	37.9 (94)	12.9 (32)	0.0 (0)
Exercises too difficult (n=249)	18.1 (45)	48.6 (121)	29.3 (73)	3.6 (9)	0.4 (1)
Exercises are boring (n=247)	11.7 (29)	38.1 (94)	33.2 (82)	15.0 (37)	2.0 (5)
The programme is too rigid (n=248)	10.5 (26)	31.9 (79)	44.4 (110)	11.7 (29)	1.6 (4)
I am not motivated enough (n=248)	19.0 (47)	41.5 (103)	29.0 (72)	10.1 (25)	0.4 (1)
There is no ball/hurley involved (n=247)	14.6 (36)	30.4 (75)	31.2 (77)	21.5 (53)	2.4 (6)
There is no training available to teach me (n=246)	14.2 (35)	30.5 (75)	20.7 (51)	27.6 (68)	6.9 (17)
I don't believe that using an IPEP will reduce injuries (n=246)	34.1 (84)	47.6 (117)	10.2 (25)	4.9 (12)	3.3 (8)

%: percentage; n: number; IPEP: injury prevention exercise programmes; AT: athletic therapist.

6.3.4 Access to Athletic Development Coaches and Medical Personnel

Just under half of coaches had access to an athletic development coach with their team (47.7%). A significantly greater number of men coaches (51.6%) had access compared with women coaches (35.6%), with a small effect size (p=0.04, phi=0.17). Similarly, elite coaches (87.5%) also had greater access to athletic development coaches compared with non-elite coaches (43.4%) (p<0.01, phi=0.26). There was also a significant difference between access to athletic development coaches and the gender of the sport that they coach (p<0.01, phi=0.22). Post-hoc comparisons found that coaches coaching women only (32.8%) had significantly less access to athletic development coaches compared with coaches coaching men only (55.8%) (r=0.22, p<0.01) and coaches coaching both men and women (53.7%) (r=0.20, p=0.01). There was no significant difference in access between coaches who have completed a Gaelic games coaching course (p=0.11, phi=0.11). Access to medical personnel is described in Table 6.6. Overall, 34.7% of teams had access to medical personnel at least every match. Almost half of the coaches coaching men's teams only (56.0%) stated that they had access to medical personnel at least every match. However, 57.4% of coaches that coached females only stated that they never had access to medical personnel.

6.3.5 Preseason screening

Almost a third of coaches (23.2%) conducted preseason screening with their team to evaluate the risk of injury. A greater proportion of male coaches (27.2%) conduct preseason screening compared to female coaches (10.5%) with small effect size (p<0.01, phi=0.21). A greater proportion of elite coaches (65.0%) conducted preseason screening compared to non-elite coaches (18.4%) with medium effect size (p<0.01, phi=0.33). There was a significant difference in coaches that conducted preseason screening and the gender of the sport they coached (p=0.01, phi=0.23). Post-hoc comparisons found that coaches coaching women only (10.3%) conducted significantly less preseason screening compared with coaches coaching men only (30.8%) (r=0.23, p<0.01) and coaches coaching both men and women (25.9%) (r=0.20, p=0.01). There was no significant difference in preseason screening between coaches who have completed a Gaelic games coaching course (p=0.10, phi=0.12).

Table 6. 6. Gaelic games teams access to medical personnel.

	Every training and match % (n)	One training a week and every match % (n)	Every match only % (n)	Champions hip match only % (n)	Every trainin g only % (n)	One training a week only % (n)	Occasional % (n)	Never % (n)
Total	10.6 (36)	5.6 (19)	18.5 (63)	8.5 (29)	0.6 (2)	0.6 (2)	18.2 (62)	37.4 (128)
				Gender				
Male coach	11.4 (29)	6.3 (16)	21.7 (55)	8.3 (21)	0.8 (2)	0.8 (2)	16.5 (42)	34.3 (87)
Female coach	7.0 (6)	3.5 (3)	9.3 (8)	9.3 (8)	0.0 (0)	0.0 (0)	23.3 (20)	47.7 (41)
				Gaelic games code				
Gaelic football	12.4 (11)	4.5 (4)	30.3 (27)	6.7 (6)	1.1 (1)	1.1 (1)	23.6 (21)	20.2 (18)
Hurling	27.6 (8)	10.3 (3)	24.1 (7)	10.3 (3)	0.0 (0)	0.0 (0)	13.8 (4)	13.8 (4)
Ladies Gaelic football	2.9 (2)	0.0 (0)	5.7 (4)	8.6 (6)	0.0 (0)	0.0 (0)	25.7 (18)	57.1 (40)
Camogie	13.8 (4)	3.4 (1)	6.9 (2)	10.3 (3)	0.0 (0)	0.0 (0)	13.8 (4)	51.7 (15)
Both men and women Gaelic football	12.8 (5)	7.7 (3)	20.5 (8)	2.6 (1)	0.0 (0)	0.0 (0)	17.99 (7)	38.5 (15)
Both hurling and Camogie	20.0 (3)	6.7 (1)	20.0 (3)	13.3 (2)	0.0 (0)	0.0 (0)	6.7 (1)	33.3 (5)
Both male codes	5.5 (3)	10.9 (6)	18.2 (10)	12.7 (7)	1.8 (1)	1.8 (1)	12.7 (7)	36.4 (20)
Both female codes	0.0 (0)	6.7 (1)	13.3 (2)	6.7 (1)	0.0 (0)	0.0 (0)	0.0 (0)	73.3 (11)
				Level of play				
Elite	40.6 (13)	9.4 (3)	28.1 (9)	6.3 (2)	3.1 (1)	0.0 (0)	6.3 (2)	6.3 (2)
Non-Elite	7.5 (23)	5.2 (16)	17.2 (53)	8.8 (27)	0.3 (1)	0.6 (2)	19.5 (60)	40.9 (126)

Gender of the sport they are Coaching								
Men only	12.8 (22)	7.6 (13)	25.6 (44)	8.7 (15)	1.2 (2)	1.2 (2)	18.6 (32)	24.4 (42)
Women only	5.2 (6)	1.7 (2)	7.0 (8)	9.6 (11)	0.0 (0)	0.0 (0)	19.1 (22)	57.4 (66)
Both men and women	14.8 (8)	7.4 (4)	20.4 (11)	5.6 (3)	0.0 (0)	0.0 (0)	14.8 (8)	37.0 (20)
Gaelic Games coaching course completed								
Yes	6.0 (7)	4.3 (5)	15.4 (18)	12.0 (14)	0.0 (0)	0.8 (1)	20.5 (24)	41.0 (48)
No	12.9 (29)	6.3 (14)	20.1 (45)	6.7 (15)	0.9 (2)	0.4 (1)	6.3 (14)	35.7 (80)

%: percentage; n: number.

6.4 Discussion

This study aimed to understand Gaelic games coaches’ awareness of, use and perceived ability to implement an injury prevention exercise programme with their team. Further, we aimed to investigate coaches' attitudes towards injury and injury prevention and the barriers and facilitators to successful injury prevention exercise programme implementation. Over 2 in every 5 Gaelic games coaches (44.1%) stated that they were aware of a specific Gaelic games injury prevention exercise programme, and 7 in every 10 of these correctly identified an injury prevention exercise programme. Thus, only 34.8% of all Gaelic games coaches are aware of and can name a specific injury prevention exercise programme. This is similar to the low awareness reported by Camogie coaches (32%) (O’Connor et al., 2020), Canadian high school rugby coaches (27%) (Shill et al., 2021), and youth male soccer coaches (16%) (De Ste Croix et al., 2020). However, this is much less than coaches' awareness in youth soccer (58-65%) (Donaldson et al., 2018; Morgan et al., 2018), youth rugby (75%) (Barden et al., 2021), high school basketball and soccer (52%) (Norcross et al., 2016) and European amateur soccer (42.6%) (Wilke et al., 2018). Low awareness is particularly worrying as awareness is the critical first step in the implementation process (Finch and Donaldson, 2010). Similar to what has been reported in Camogie coaches (O’Connor et al., 2020), 36.2% of coaches in this study believed that injuries were an issue with their team, and despite this, they are not aware that injury prevention exercise programmes are available to them that could reduce the risk of injury. The cost of an injury can be burdensome, with the mean cost of men's Gaelic games claims being €1158.40 (Roe et al., 2016), and the mean cost of Ladies Gaelic football claims being €663.30 (O’Connor et al., 2022), with claims in both increasing annually. Three in every five claims made are for lower limb injuries, which have been the focus of injury prevention exercise programme, with the GAA15 proven to reduce lower limb injuries (Schlingermann et al., 2018; Kelly and Lodge, 2018). Therefore, greater efforts are needed from an organisational level to increase awareness because, in Gaelic games especially (a community sport) (Finch and Donaldson, 2010), the coach is primarily responsible for deciding whether to use an injury prevention exercise programme. There was a significant difference in awareness between the gender of the coaches and the gender of the sport they coached with female coaches, and those coaching female Gaelic games were less aware of injury prevention exercise programme. Previously it was thought that there would be a greater awareness in females due to the increased risk of more severe injuries in females (Perera and Hägglund, 2020). However, this was not the case in Gaelic games. The LGFA and Camogie Association need to target coaches and increase awareness of injury prevention exercise programmes with female coaches and coaches of female teams as women may have less access to medical care (Parsons et al., 2021), and discrepancies in funding between men's and women's sports (Kelly et al., 2022). Therefore, coaches may have increased responsibility to deliver injury prevention exercise programmes with their team.

Three in every five Gaelic games coaches stated they used an injury prevention exercise programme. This is almost double what was reported in camogie (34%) (O'Connor et al., 2020) and much more than in Gaelic football (7.2%) (Reilly and Kipps, 2017). However, it must be noted that the Gaelic football study had a small sample size and only included two counties (Reilly and Kipps, 2017). Thus, while the widespread use of injury prevention exercise programmes is still relatively low, it has increased in recent years. Coaches with elite teams utilised injury prevention exercise programmes more than non-elite coaches, which may be explained by the greater access to athletic development coaches and medical personnel who have been identified as essential programme implementers in professional sports (O'Brien and Finch, 2017). Therefore, clubs and organisations need to educate coaches on injury prevention exercise programme, particularly coaches of non-elite teams, as coaches are in a distinctive position to encourage injury prevention, safe play, and make rapid choices on injury management (Carter and Muller, 2008), particularly in amateur sports such as Gaelic games. The main reasons for coaches not using an injury prevention exercise programme were a lack of skill set and resources. While the Gaelic games injury prevention exercise programmes are freely available online and require no external resources, additional education and support are needed to enhance their confidence in delivering these injury prevention exercise programmes. Thus, mandatory, practical injury prevention workshops may be necessary, and 95.5% of Camogie coaches previously stated that they would be likely to attend one (O'Connor et al., 2020), and 61.6% of Gaelic games chose a workshop as the form of educational opportunity they would like to participate in (Horgan et al., 2021). Previous research has shown in Camogie coaches that an injury prevention workshop with both theory and practical elements enhanced coaches' attitudes towards injury prevention, increased the implementation and maintenance of an injury prevention exercise programme and enhanced their perceived ability in their skill to conduct the injury prevention exercise programme (O'Connor and Lacey, 2020). Similarly, participation in a coaching workshop on FIFA 11+ training is reported to have increased programme adherence compared to only giving out instructional materials (Steffen et al., 2013). Injury prevention education is now embedded in Camogie coaches' education, but educational injury prevention workshops should be made mandatory for all Gaelic games codes as they are effective, and coaches would like to attend them.

Although the Gaelic games specific injury prevention exercise programmes are designed to be utilised before all training sessions and games, only a third (35.8%) of the teams who use an injury prevention exercise programme do so as directed. A large proportion of coaches (44%) using an injury prevention exercise programme designate less than 10 mins for injury prevention which is less than the recommended time. Injury prevention exercise programmes can only be effective if they are delivered as intended (Finch, 2006). Future studies are needed to investigate the minimal dose required for injury prevention exercise programmes, but until then, injury prevention exercise programmes should be used every training and match as directed. Coaches also believe (92.7%) that injury prevention exercise programmes must be varied and progress over time. These elements were previously thought to be crucial for inspiring players, preventing monotony, and tailoring the exercises to individual players' various skill level (O'Brien et al., 2017). The Activate has some variation of the exercise, which may explain why it was the most used injury prevention exercise programme amongst Gaelic games coaches. However, the GAA15 has no variation or progressions. Coaches must contribute to the creation of the injury prevention exercise programmes from the start (Bekker and Clark, 2016). A large proportion of coaches coaching females were modifying injury prevention exercise programmes or creating their own. This could be because coaches feel that the current Gaelic games injury prevention exercise programmes don't apply to women's sports context, as a lack of consideration for gender differences was a barrier to injury prevention exercise programme use in LGFA (Corrigan et al., 2023). Further qualitative research is needed to investigate why so many coaches create their own injury prevention exercise programmes, particularly in Ladies' Gaelic games. Understanding why coaches alter injury prevention exercise programmes is essential, as determining if the alterations could influence (either favourably or adversely) the programme's efficacy (O'Brien et al., 2017). It was previously found that lower compliance or injury prevention exercise programme fidelity was associated with an increased injury rate in male players (Åkerlund et al., 2022; Krug et al., 2022; Silvers-Granelli et al., 2018). However, allowing coaches autonomy might increase coach compliance, particularly their willingness to adopt the injury prevention exercise programmes (O'Connor et al., 2021). Although no previous research has looked at programme fidelity in Gaelic games injury prevention exercise programmes, based on the current research in other sports, poor programme fidelity would likely lead to less-than-optimal programme effectiveness in Gaelic games. Therefore, the Gaelic games organisations must include Gaelic games coaches in the design phase of injury prevention exercise programmes. This will aid in coach motivation to use the programmes as designed. However, until further research is conducted on fidelity and the refinement of injury prevention exercise programmes, the Gaelic games governing bodies, particularly the LGFA and Camogie Association, must prioritise player welfare and injury prevention. This could be achieved by supporting the coaches of female Gaelic games by facilitating injury prevention webinars and practical workshops.

Two-fifths of coaches were not using an injury prevention exercise programme but could be using general injury prevention practices. The most popular injury prevention practices were a warm-up (89.0%), stretching (80.5%) and a cool-down (69.4%). This is similar to basketball and Canadian rugby coaches, where 95.9% and 85% of coaches implement a warm-up, respectively (Räisänen et al., 2021; Shill et al., 2021). The large proportion of coaches using a warm-up in Gaelic games is promising as it shows a willingness to adopt injury prevention practices; therefore, there is great potential to encourage coaches to use an efficacious injury prevention exercise programme warm-up. Gaelic games coaches rated stretching and warm-up as the training practice most effective for injury prevention. Balance, plyometric and strength training were not rated effective in preventing injuries in Gaelic games. Resistance training has been demonstrated to reduce injuries by 69%, compared to stretching's 4% reduction (Lauersen et al., 2014). Some of the practices used by Gaelic games coaches are not always backed by evidence; thus, educating coaches on the most effective practices for injury prevention will lead to a greater injury risk reduction for Gaelic games players. The results indicate a general willingness to employ injury prevention practice. However, there needs to be both a top-down and bottom-up approach, where researchers listen to the stakeholders and contextual factors to increase adoption. The Gaelic games injury prevention exercise programmes themselves may need to be adapted to meet the needs of coaches, but also coaches need to be educated on the essential aspects of injury prevention if there is going to be an effective injury risk reduction in Gaelic games.

It takes the engagement of many vital stakeholders to improve injury prevention exercise programme uptake and implementation in real community sports settings (Bekker and Clark, 2016). It is also critical to understand how stakeholders feel about injury prevention and how it fits into their lifestyles and the game's culture (Finch, 2006). Therefore, it is crucial to understand Gaelic games coaches' attitudes to injury prevention. Over nine in every ten Gaelic games coaches believe that injuries can shorten a player's career, and three in every four coaches (74.2%) believe Gaelic games players are at a high risk of injury. Almost nine in every ten (87.6%) coaches believe that injuries can have a negative impact on team performance. Research has shown that injuries negatively affect team success in professional soccer (Hägglund et al., 2013), professional rugby (Williams et al., 2016), and Australian rules football (Hoffman et al., 2020). Most coaches believe it is important to have current knowledge of injury prevention exercise programmes (95.7%), and 95.3% believe that injury prevention is important during training. Coaches understand the negative impacts that injury can have, and there is potential for encouraging the use of an injury prevention exercise programme. Therefore, it is paramount that organisations emphasise educating these volunteer coaches on how to deliver an injury prevention exercise programme to their team, as coaches understand the risks involved with Gaelic games and would like to be kept up to date with the research.

For evidence-based injury prevention exercise programmes to have a meaningful impact on preventing injuries, they must be employed widely and regularly (Donaldson et al., 2017). Understanding the barriers and facilitators in a Gaelic games setting is critical to injury prevention exercise programme implementation (Benjaminse and Verhagen, 2021). Coaches stated that having an athletic development coach (91.5%) or an athletic therapist/physiotherapist (87.5%) lead their team in injury prevention exercise programmes were the greatest facilitators of using an injury prevention exercise programme. However, most teams have no access to athletic development coaches or medical personnel (Table 6.6). Moreover, the top three barriers were that the coach doesn't have the knowledge of how to use it (40.6%), there is no training available to teach them (34.5%), and their team doesn't have someone with the appropriate skill/knowledge (31.3%). However, injury prevention exercise programmes have been developed so coaches without a background in the health sciences can use them (Finch and Donaldson, 2010; Dix et al., 2021). The transmission of information about an invention (injury prevention exercise programme) to a potential user without a structured dissemination campaign relies significantly on mass media and human contacts (Rogers, 1983). Therefore, organisations need to adopt an injury prevention strategy to maximise awareness, use and fidelity of injury prevention exercise programmes.

Limitations

This study was the first to investigate the implementation of injury prevention exercise programmes across all Gaelic games codes and coaches' attitudes towards injury prevention. Coaches more engaged in injury prevention were more likely to complete this study as it employed a convenience sampling strategy, and respondents chose to participate on a self-selected basis. Similarly, the sample size may not be generalizable to all Gaelic Games coaches and it is unknown how many coaches actually received the survey. Respondent's answers to the survey's Likert scale questions may have been influenced by central tendency bias, acquiescence bias, or social desirability bias. Gaining a more profound knowledge of end-user attitudes and contextual challenges in adopting injury prevention exercise programmes may be aided by additional qualitative research.

6.5 Conclusion

Although efficacious injury prevention exercise programmes have been developed in Gaelic games, injury prevention requires much more than an effective programme. For any change in injury rates, the efficacious injury prevention exercise programmes must be accepted, used and maintained with high fidelity by the end users. However, less than half of Gaelic games coaches were aware that Gaelic games injury prevention exercise programmes existed, and just over a third were using a specific Gaelic games injury prevention exercise programme. Where injury prevention exercise programmes were used, fidelity was low. There is a potential for organisations and clubs to encourage coaches to use injury prevention exercise programmes and enhance coaches' skills in delivering injury prevention exercise programmes as Gaelic games coaches acknowledge the negative impact injuries can have, and they have a positive attitude towards injury prevention. This could be achieved by acknowledging some barriers and facilitators identified by Gaelic games coaches, such as more training in delivering injury prevention exercise programmes and better resources, such as access to medical personnel and coaches. Similarly, organisations need to include coaches in the development of injury prevention strategies. A greater emphasis must be placed on educating coaches across all codes of Gaelic games, but particularly coaches involved with female teams due to their lower use of effective injury prevention exercise programmes and high proportion of coaches modifying or developing their own programme.

Chapter 7 Overall Discussion and Future Recommendation

7.1 Overall Discussion of Thesis

The literature review for this thesis revealed a gap in understanding of the injuries in Gaelic games, particularly in hurling and Camogie and the burden of injury. Similarly, there is a lack of an understanding of the risk factors for hamstring injury, which is the most common injury in Gaelic games. The implementation of injury prevention exercise programmes is an effective way of reducing injury rates in sports (Mendonça et al., 2021). However, the literature review revealed a dearth of information regarding the implementation of injury prevention exercise programmes in Gaelic games. All of these shortcomings are critical stages of the TRIPP framework and factors that lead to injury prevention (Finch, 2006). This thesis adds to the epidemiological research in Gaelic games. As indicated in the literature review in Chapter 2, injuries are prevalent in Gaelic games. A finding reiterated in Chapter 3 with 23.0% of Gaelic games players sustaining an injury during the academic season. A higher proportion of female Gaelic games players (26.5%) suffered an injury than male Gaelic players (20.8%), indicating that future injury prevention interventions should target the female Gaelic games player. This is critical as it is well established that injury is one of the leading causes of drop-out from sport. The injury rate in matches was almost five times greater than in training. Although there is increased competition and possible physicality in matches, this finding suggests that players are not adequately prepared for the demands of matches. It has been well established that injury prevention exercise programmes developed for Gaelic games effectively reduce injury in a controlled environment, but the high injury rates suggest that either coaches aren't using them for one reason or another or the programmes are not as effective in the real world setting. Therefore, further research should investigate what coaches would like to have included in an injury prevention exercise programme and what resources would make it easier to implement them with their team.

A common finding in the literature is that lower limb injuries occur most frequently, as found in Chapter 3. In Gaelic football, one in five injuries sustained was a hamstring muscle strain which also had the largest burden of all injuries (55.3 days absent per 1000 hours). However, in hurling/Camogie, the most common injury was a calf muscle strain. Despite this, hamstring muscle strains had the largest burden of injury (17.1 days absent per 1000 hours). Reducing hamstring injuries would significantly lower the total injury rates in Gaelic games and should be the focus of injury prevention interventions. The Nordic hamstring exercise can half hamstring injury rates (van Dyk et al., 2019) and, therefore should be incorporated into injury prevention interventions. The four Gaelic games-specific injury prevention exercise programmes include the Nordic hamstring exercise, but unfortunately, hamstring injury rates and burden remain high. Further research is needed to investigate if programme and exercise fidelity, as coaches that state they are using an injury prevention exercise programme, could be leaving out certain crucial aspects of the programme. Furthermore, it is critical that further risk factors for hamstring injuries are explored and interventions tailored to those at the greatest risk of injury. Similarly, it is imperative that coaches are educated about the benefits of using an exercise such as the Nordic hamstring exercise that could reduce the number of injuries in their team and potentially lead to greater success.

In Chapter 4, it was found that 24% of Gaelic footballers sustained a hamstring injury with a mean time loss due to injury of almost 17 days. The previous literature suggests that non-modifiable risk factors such as previous hamstring injury and increased age have the most significant association with the risk of a hamstring injury (Green et al., 2020). Chapter 4 corroborates this finding in elite male Gaelic footballers. However, increased jump height on the CMJ at preseason was also associated with the risk of sustaining a hamstring injury. This is a novel finding in Gaelic games and hamstring injury risk research which could be a result of strength and conditioning programmes including more quadricep-dominant exercises than hamstring-dominant exercises which could lead to an imbalance. However, this warrants further investigation which could include strength testing of both the hamstrings and quadriceps and their association with hamstring injuries. Gaelic football players that suffered a hamstring injury had significantly greater exposure to high-speed running distance and sprint distance and completed a more significant number of high-intensity sprint efforts and sprints >22km/h than uninjured players on the week of their injury. Therefore monitoring high-speed exposures is recommended, and avoiding any significant irregularities or pauses in exposure to high-speed running should be avoided. It is also critical that coaches condition their players for the demands of the game. Coaches need to remember that a player's exposure to high-speed running may depend on various personal, environmental and contextual factors, including the players' ability, the sport they play, their position, and the level they are playing at, among other factors.

As outlined in the previous Chapters, injuries are common in Gaelic games. The implementation of injury prevention exercise programmes is an effective way of reducing injury rates in sports (Mendonça et al., 2021). Several Gaelic games-specific injury prevention exercise programmes have been developed and adopted by the Gaelic games governing bodies that effectively reduce injuries and risk factors for injuries in a controlled environment, but this does not seem to be translating to a reduction of injuries in the real world. However, until now, it was unknown the awareness of, use of, and attitudes towards these programmes were among critical stakeholders in Gaelic games. Chapters 5 and 6 are the first to extensively investigate this in both adult players and coaches across all Gaelic games codes. A number of critical findings were made that will advance injury prevention practices. Almost two-thirds of players stated awareness of an injury prevention exercise programme, yet only 13.4% indicated awareness and could correctly name a programme. The use of injury prevention exercise programmes was also low, with 31.7% of players saying that a programme was used with their team. There was lower use of injury prevention exercise programmes among female Gaelic games players, which may explain why more females were injured in Chapter 3. Therefore, it is critical that the relevant governing bodies, particularly the LGFA and Camogie Association, educate coaches on the benefits of using an injury prevention exercise programme and put the relevant infrastructure in place to support coaches and clubs in delivering interventions. Coaches were more aware of injury prevention programmes (44.1%). However, only a third of coaches stated awareness and correctly named a Gaelic games-specific programme which is relatively low considering that injury prevention exercise programmes for Gaelic games have been in existence since 2006, and the high injury rates and burden associated with injury in Gaelic games. Three-fifths of coaches (59.5%) stated they were using an injury prevention exercise programme, yet 23.6% of these were modifying or creating their own programme. Therefore, only 29.2% of coaches used a Gaelic games-specific injury prevention exercise programme with their team. More coaches coaching female teams (33.5%) were modifying or creating their own programme compared to coaches coaching male teams (20.2%). Therefore, the LGFA and Camogie Association must do more to educate coaches and increase awareness of coaches of the already established effective injury prevention exercise programmes.

The Activate GAA warmup and the GAA15 were the two most popular used programmes by players and coaches. However, of those that said they used a programme, only 41.6% of players and 35.8% of coaches used it every training session and match, which is the recommended use. Thus, even with the low usage among stakeholders, programme fidelity is low. Reasons given by coaches for not using an injury prevention exercise programme included lack of skill set (20.6%) and lack of resources (19.0%). Players had a more negative outlook towards injuries than their coaches. There was a discrepancy in agreement between players (68.2%) and coaches (36.2%) for injuries being an issue with their team. Players (41.6%) also lacked confidence that their coaches had knowledge of injury prevention exercise programmes. Although the awareness and use of injury prevention exercise programmes are low amongst key stakeholders, both players and coaches had a positive attitude towards them. A similar amount of players (95.7%) and coaches (95.3%) agree that injury prevention is an important aspect of training. Similarly, 91.4% of players and 91.5% of coaches believe that using an injury prevention exercise programme will reduce the number of injuries for their team. Consequently, due to the positive attitude, there is a desire for injury prevention exercise programmes which the Gaelic games governing bodies need to harness with the correct approach by placing an emphasis on injury prevention and player welfare. The Gaelic games associations have an excellent opportunity to educate stakeholders on the importance of their injury prevention exercise programmes and provide education and assistance for coaches on the delivery of programmes. This could be achieved by making mandatory workshops as part of coaching education and potentially adapting the current resources for female Gaelic games players due to the high amount of coaches modifying them.

To summarise, this thesis further adds to the existing knowledge on the epidemiology of injury in Gaelic games and explores risk factors for hamstring injuries in Gaelic games, which is the first and second stage of the TRIPP framework for injury prevention. Finally, the thesis explores the fifth stage of the TRIPP framework by determining key stakeholders' attitudes and the context in which injury prevention exercise programmes are to be implemented.

This is a critical step needed if efforts to lower injury rates and the burden of injury in Gaelic games succeed (Bolling et al., 2018; Finch, 2006).

7.2 Future Directions

There are several areas that pose a need for more research based on the results of this thesis.

- Firstly, chapter 3 focused on injury epidemiology in collegiate Gaelic games players. Further research should incorporate club players and underage players who comprise most of the Gaelic games community. Long term surveillance of injuries is needed to see if injury prevention exercise programmes that are being implemented are effective in the real-world.
- As the academic season is short, future studies should focus on a more longitudinal duration across a number of years and monitor players' exposure to the various teams they could be training with concurrently.
- Risk factors for hamstring, knee and ankle injuries should be tested and monitored regularly instead of once off at preseason as risk factors can fluctuate throughout a season. These locations are critical as they have the greatest burden of injury in Gaelic games players. Similarly, injury prevention exercise programmes should focus on trying to limit these injuries.
- Chapter 4 focused solely focused on elite male Gaelic footballers. This study should be replicated on Ladies Gaelic football and hurling/Camogie as risk factors for injuries should not be generalised between sports. The study should also be repeated over a longer prospective period.
- Increased jump height on the CMJ was identified as a risk factor for a hamstring injury. This needs to be investigated further to explain the relationship and mechanisms at play. We suggest that this may be due to a quadricep:hamstring imbalance; however, this is still unknown.
- Although we found no differences in any of the performance tests during the different time-points, monitoring potential risk factors on a more regular basis is recommended over a greater duration and is crucial in setting standards to reach when returning to play from injury.
- It is recommended that subjective wellness, recovery, perceived fatigue and pain scores and their association with injury in Gaelic games players should also be explored.

- Chapters 5 and 6 focused on two key stakeholders for implementing the injury prevention exercise programme. However, it is also essential to understand key figures within the club structure, such as development and coaching officers' attitudes towards injury prevention. Coaches can frequently change within clubs, so making sure that the club officers have a positive attitude towards injury prevention could be critical to their implementation and long-lasting success.
- Chapters 5 and 6 also used a quantitative examination. Future studies should focus on qualitative research which to date has only been completed on Ladies Gaelic football. Qualitative research will provides for more thorough explanations of factors that directly impact stakeholders and gives a better insights into their opinion
- The Gaelic games associations need to acknowledge some of the barriers identified by the stakeholders and introduce measures to counteract these. This may be achieved by injury prevention workshops which have previously been trialled and successful in Camogie. Alternatively, associations should make an injury prevention module mandatory so that all coaches have training in their delivery.
- Several programmes have been developed and proven effective in a controlled environment. Although the use of the programmes is limited, future research should investigate the effectiveness of the programmes in the real-world sporting context. Similarly, coaches that are implementing programmes should be observed for the programme and exercise fidelity as injury rates remain high in Gaelic games.

Bibliography

Agel, Julie, Todd A Evans, Randall Dick, Margot Putukian, and Stephen W Marshall. 2007. "Descriptive Epidemiology of Collegiate Men's Soccer Injuries: National Collegiate Athletic Association Injury Surveillance System, 1988–1989 Through 2002–2003." *Journal of Athletic Training* 47 (2): 270–77.

Åkerlund, Ida, Markus Waldén, Sofi Sonesson, Hanna Lindblom, and Martin Hägglund. 2022. "High Compliance with the Injury Prevention Exercise Programme Knee Control Is Associated with a Greater Injury Preventive Effect in Male, but Not in Female, Youth Floorball Players." *Knee Surgery, Sports Traumatology, Arthroscopy* 30 (4): 1480–90. https://doi.org/10.1007/s00167-021-06644-2.

Al Attar, Wesam Saleh A., and Mansour Abdullah Alshehri. 2019. "A Meta-analysis of Meta-analyses of the Effectiveness of FIFA Injury Prevention Programs in Soccer." *Scandinavian Journal of Medicine & Science in Sports* 29 (12): 1846–55. https://doi.org/10.1111/sms.13535.

Al Attar, Wesam Saleh A., Najeebullah Soomro, Peter J. Sinclair, Evangelos Pappas, and Ross H. Sanders. 2017. "Effect of Injury Prevention Programs That Include the Nordic Hamstring Exercise on Hamstring Injury Rates in Soccer Players: A Systematic Review and Meta-Analysis." *Sports Medicine* 47 (5): 907–16. https://doi.org/10.1007/s40279-016-0638-2.

Alba-Jiménez, Claudia, Daniel Moreno-Doutres, and Javier Peña. 2022. "Trends Assessing Neuromuscular Fatigue in Team Sports: A Narrative Review." *Sports* 10 (3): 33. https://doi.org/10.3390/sports10030033.

Allen, Trevor J., Michael Leung, and Uwe Proske. 2010. "The Effect of Fatigue from Exercise on Human Limb Position Sense: Effect of Fatigue on Human Limb Position Sense." *The Journal of Physiology* 588 (8): 1369–77. https://doi.org/10.1113/jphysiol.2010.187732.

Anderson, Gregory R., Heath P. Melugin, and Michael J. Stuart. 2019. "Epidemiology of Injuries in Ice Hockey." *Sports Health: A Multidisciplinary Approach* 11 (6): 514–19. https://doi.org/10.1177/1941738119849105.

Arnason, Arni, Stefan B Sigurdsson, Arni Gudmundsson, Ingar Holme, Lars Engebretsen, and Roald Bahr. 2004. "Risk Factors for Injuries in Football." *The American Journal of Sports Medicine* 32 (1): 12.

Arundale, Amelia J. H., Holly J. Silvers-Granelli, and Grethe Myklebust. 2022. "ACL Injury Prevention: Where Have We Come from and Where Are We Going?" *Journal of Orthopaedic Research* 40 (1): 43–54. https://doi.org/10.1002/jor.25058.

Askling, Carl M, Nikolaos Malliaropoulos, and Jon Karlsson. 2012. "High-Speed Running Type or Stretching-Type of Hamstring Injuries Makes a Difference to Treatment and Prognosis." *British Journal of Sports Medicine* 46 (2): 86–87. https://doi.org/10.1136/bjsports-2011-090534.

Askling, Carl M., Magnus Tengvar, Tönu Saartok, and Alf Thorstensson. 2007a. "Acute First-Time Hamstring Strains during High-Speed Running: A Longitudinal Study Including Clinical and Magnetic Resonance Imaging Findings." *The American Journal of Sports Medicine* 35 (2): 197–206. https://doi.org/10.1177/0363546506294679.

———. 2007b. "Acute First-Time Hamstring Strains during Slow-Speed Stretching: Clinical, Magnetic Resonance Imaging, and Recovery Characteristics." *The American Journal of Sports Medicine* 35 (10): 1716–24. https://doi.org/10.1177/0363546507303563.

Askling, Carl M., Magnus Tengvar, Tonu Saartok, and Alf Thorstensson. 2008. “Proximal Hamstring Strains of Stretching Type in Different Sports: Injury Situations, Clinical and Magnetic Resonance Imaging Characteristics, and Return to Sport.” *The American Journal of Sports Medicine* 36 (9): 1799–1804. https://doi.org/10.1177/0363546508315892.

Avrillon, Simon, François Hug, and Gaël Guilhem. 2020. “Bilateral Differences in Hamstring Coordination in Previously Injured Elite Athletes.” *Journal of Applied Physiology* 128 (3): 688–97. https://doi.org/10.1152/japplphysiol.00411.2019.

Bahr, R. 2009. “No Injuries, but Plenty of Pain? On the Methodology for Recording Overuse Symptoms in Sports.” *British Journal of Sports Medicine* 43 (13): 966–72. https://doi.org/10.1136/bjsm.2009.066936.

Bahr, R, and I. Holme. 2003. “Risk Factors for Sports Injuries -- a Methodological Approach.” *British Journal of Sports Medicine* 37 (5): 384–92. https://doi.org/10.1136/bjsm.37.5.384.

Bahr, R, and T Krosshaug. 2005. “Understanding Injury Mechanisms: A Key Component of Preventing Injuries in Sport.” *British Journal of Sports Medicine* 39 (6): 324–29. https://doi.org/10.1136/bjsm.2005.018341.

Bahr, Roald. 2016. “Why Screening Tests to Predict Injury Do Not Work—and Probably Never Will…: A Critical Review.” *British Journal of Sports Medicine* 50 (13): 776–80. https://doi.org/10.1136/bjsports-2016-096256.

Bahr, Roald, Ben Clarsen, Wayne Derman, Jiri Dvorak, Carolyn A. Emery, Caroline F. Finch, Martin Hägglund, et al. 2020. “International Olympic Committee Consensus Statement: Methods for Recording and Reporting of Epidemiological Data on Injury and Illness in Sports 2020 (Including the STROBE Extension for Sports Injury and Illness Surveillance (STROBE-SIIS)).” *Orthopaedic Journal of Sports Medicine* 8 (2): 232596712090290. https://doi.org/10.1177/2325967120902908.

Bahr, Roald, Benjamin Clarsen, and Jan Ekstrand. 2017. “Why We Should Focus on the Burden of Injuries and Illnesses, Not Just Their Incidence.” *British Journal of Sports Medicine52* 0 (16): 1018–21.

Ball, K, and B Horgan. 2013. “Performance Analysis of Kicking and Striking Skills in Gaelic Sports.” In *Performance Analysis of Sport IX*, edited by M Peters and P O’Donoghue, 9th ed., 117–23. Routledge.

Ball, Kevin. 2008. “Biomechanical Considerations of Distance Kicking in Australian Rules Football.” *Sports Biomechanics* 7 (1): 10–23. https://doi.org/10.1080/14763140701683015.

Bangsbo, Jens, Magni Mohr, and Peter Krustrup. 2006. “Physical and Metabolic Demands of Training and Match-Play in the Elite Football Player.” *Journal of Sports Sciences* 24 (7): 665–74. https://doi.org/10.1080/02640410500482529.

Barber Foss, Kim D., Ed Le Cara, Teri McCambridge, Richard Y. Hinton, Adam Kushner, and Gregory D. Myer. 2018. “Epidemiology of Injuries in Women’s Lacrosse: Implications for Sport-, Level-, and Sex-Specific Injury Prevention Strategies.” *Clinical Journal of Sport Medicine* 28 (4): 406–13. https://doi.org/10.1097/JSM.0000000000000458.

Barden, Craig, Sheree Bekker, James Craig Brown, Keith A Stokes, and Carly D. McKay. 2021. “Evaluating the Implementation of Injury Prevention Strategies in Rugby Union and League: A Systematic Review Using the RE-AIM Framework.” *International Journal of Sports Medicine* 42 (02): 112–21. https://doi.org/10.1055/a-1212-0649.

Barden, Craig, Keith A Stokes, and Carly D McKay. 2021. "Implementation of the *Activate* Injury Prevention Exercise Programme in English Schoolboy Rugby Union." *BMJ Open Sport & Exercise Medicine* 7 (2): e001018. https://doi.org/10.1136/bmjsem-2020-001018.
Barker, Leland A., John R. Harry, and John A. Mercer. 2018. "Relationships Between Countermovement Jump Ground Reaction Forces and Jump Height, Reactive Strength Index, and Jump Time." *Journal of Strength and Conditioning Research* 32 (1): 248–54. https://doi.org/10.1519/JSC.0000000000002160.
Bartlett, Jonathan D., and Barry Drust. 2021. "A Framework for Effective Knowledge Translation and Performance Delivery of Sport Scientists in Professional Sport." *European Journal of Sport Science* 21 (11): 1579–87. https://doi.org/10.1080/17461391.2020.1842511.
Battermann, N., H.-J. Appell, J. Dargel, and J. Koebke. 2011. "An Anatomical Study of the Proximal Hamstring Muscle Complex to Elucidate Muscle Strains in This Region." *International Journal of Sports Medicine* 32 (03): 211–15. https://doi.org/10.1055/s-0030-1268011.
Baumert, Philipp, S. Temple, J. M. Stanley, M. Cocks, J. A. Strauss, S. O. Shepherd, B. Drust, M. J. Lake, C. E. Stewart, and R. M. Erskine. 2021. "Neuromuscular Fatigue and Recovery after Strenuous Exercise Depends on Skeletal Muscle Size and Stem Cell Characteristics." *Scientific Reports* 11 (1): 7733. https://doi.org/10.1038/s41598-021-87195-x.
Bautista, Iker J., Juan Vicente-Mampel, Luis Baraja-Vegas, Víctor Segarra, Fernando Martín, and Bas Van Hooren. 2021. "The Effects of the Nordic Hamstring Exercise on Sprint Performance and Eccentric Knee Flexor Strength: A Systematic Review and Meta-Analysis of Intervention Studies among Team Sport Players." *Journal of Science and Medicine in Sport* 24 (9): 931–38. https://doi.org/10.1016/j.jsams.2021.03.009.
Beasley, Kevin J. 2015. "Nutrition and Gaelic Football: Review, Recommendations, and Future Considerations." *International Journal of Sport Nutrition and Exercise Metabolism* 25 (1): 1–13. https://doi.org/10.1123/ijsnem.2013-0214.
Beijsterveldt, A. M. C. van, I. G. L. van de Port, A. J. Vereijken, and F. J. G. Backx. 2013. "Risk Factors for Hamstring Injuries in Male Soccer Players: A Systematic Review of Prospective Studies: Risk Factors for Hamstring Injuries." *Scandinavian Journal of Medicine & Science in Sports* 23 (3): 253–62. https://doi.org/10.1111/j.1600-0838.2012.01487.x.
Bekker, Sheree. 2019. "Shuffle Methodological Deck Chairs or Abandon Theoretical Ship? The Complexity Turn in Injury Prevention." *Injury Prevention* 25 (2): 80–82. https://doi.org/10.1136/injuryprev-2018-042905.
Bekker, Sheree, and Alexander M Clark. 2016. "Bringing Complexity to Sports Injury Prevention Research: From Simplification to Explanation." *British Journal of Sports Medicine* 50 (24): 1489–90. https://doi.org/10.1136/bjsports-2016-096457.
Beltran, Luis, Varand Ghazikhanian, Mario Padron, and Javier Beltran. 2012. "The Proximal Hamstring Muscle–Tendon–Bone Unit: A Review of the Normal Anatomy, Biomechanics, and Pathophysiology." *European Journal of Radiology* 81 (12): 3772–79. https://doi.org/10.1016/j.ejrad.2011.03.099.
Bengtsson, Håkan, Jan Ekstrand, and Martin Hägglund. 2013. "Muscle Injury Rates in Professional Football Increase with Fixture Congestion: An 11-Year Follow-up of the UEFA Champions League Injury Study." *British Journal of Sports Medicine* 47 (12): 743–47. https://doi.org/10.1136/bjsports-2013-092383.

Benjaminse, Anne, and Evert Verhagen. 2021. "Implementing ACL Injury Prevention in Daily Sports Practice—It's Not Just the Program: Let's Build Together, Involve the Context, and Improve the Content." *Sports Medicine* 51 (12): 2461–67. https://doi.org/10.1007/s40279-021-01560-4.

Bennell, Kim, Richard Talbot, Henry Wajswelner, Wassana Techovanich, David Kelly, and Aj Hall. 1998. "Intra-Rater and Inter-Rater Reliability of a Weight-Bearing Lunge Measure of Ankle Dorsiflexion." *Australian Journal of Physiotherapy* 44 (3): 175–80. https://doi.org/10.1016/S0004-9514(14)60377-9.

Benson, Lauren C., Anu M. Räisänen, Valeriya G. Volkova, Kati Pasanen, and Carolyn A. Emery. 2020. "Workload A-WEAR-Ness: Monitoring Workload in Team Sports With Wearable Technology. A Scoping Review." *Journal of Orthopaedic & Sports Physical Therapy* 50 (10): 549–63. https://doi.org/10.2519/jospt.2020.9753.

Beynnon, Bruce D., Pamela M. Vacek, Maira K. Newell, Timothy W. Tourville, Helen C. Smith, Sandra J. Shultz, James R. Slauterbeck, and Robert J. Johnson. 2014. "The Effects of Level of Competition, Sport, and Sex on the Incidence of First-Time Noncontact Anterior Cruciate Ligament Injury." *The American Journal of Sports Medicine* 42 (8): 1806–12. https://doi.org/10.1177/0363546514540862.

Bezodis, Neil Edward, Grant Trewartha, and Aki Ilkka Tapio Salo. 2015. "Understanding the Effect of Touchdown Distance and Ankle Joint Kinematics on Sprint Acceleration Performance through Computer Simulation." *Sports Biomechanics* 14 (2): 232–45. https://doi.org/10.1080/14763141.2015.1052748.

Biggs, Michael A. R., and Daniela Büchler. 2007. "Rigor and Practice-Based Research." *Design Issues* 23 (3): 62–69. https://doi.org/10.1162/desi.2007.23.3.62.

Bishop, Chris, Paul Read, Shyam Chavda, and Anthony Turner. 2016. "Asymmetries of the Lower Limb: The Calculation Conundrum in Strength Training and Conditioning." *Strength & Conditioning Journal* 38 (6): 27–32. https://doi.org/10.1519/SSC.0000000000000264.

Bishop, David. 2008. "An Applied Research Model for the Sport Sciences:" *Sports Medicine* 38 (3): 253–63. https://doi.org/10.2165/00007256-200838030-00005.

Bittencourt, N F N, W H Meeuwisse, L D Mendonça, A Nettel-Aguirre, J M Ocarino, and S T Fonseca. 2016. "Complex Systems Approach for Sports Injuries: Moving from Risk Factor Identification to Injury Pattern Recognition—Narrative Review and New Concept." *British Journal of Sports Medicine* 50 (21): 1309–14. https://doi.org/10.1136/bjsports-2015-095850.

Bizzini, Mario, and Jiri Dvorak. 2015. "FIFA 11+: An Effective Programme to Prevent Football Injuries in Various Player Groups Worldwide—a Narrative Review." *British Journal of Sports Medicine* 49 (9): 577–79. https://doi.org/10.1136/bjsports-2015-094765.

Blake, C., J. C. Murphy, C. Gissane, and E. O'Malley. 2011. "A Prospective Study of Injury in Elite Gaelic Games." *British Journal of Sports Medicine* 45 (4): 337–337. https://doi.org/10.1136/bjsm.2011.084038.76.

Blake, C., E. O'Malley, C. Gissane, and J. C. Murphy. 2014. "Epidemiology of Injuries in Hurling: A Prospective Study 2007-2011." *BMJ Open* 4 (6): e005059–e005059. https://doi.org/10.1136/bmjopen-2014-005059.

Bohannon, Richard W., David Tiberio, and Michael Zito. 1989. "Selected Measures of Ankle Dorsiflexion Range of Motion: Differences and Intercorrelations." *Foot & Ankle* 10 (2): 99–103. https://doi.org/10.1177/107110078901000209.

Bolling, Caroline, Saulo Delfino Barboza, Willem van Mechelen, and H Roeline Pasman. 2020. "Letting the Cat out of the Bag: Athletes, Coaches and Physiotherapists

Share Their Perspectives on Injury Prevention in Elite Sports.” *British Journal of Sports Medicine* 54 (14): 871–77. https://doi.org/10.1136/bjsports-2019-100773.
Bolling, Caroline, Willem van Mechelen, H. Roeline Pasman, and Evert Verhagen. 2018. “Context Matters: Revisiting the First Step of the ‘Sequence of Prevention’ of Sports Injuries.” *Sports Medicine* 48 (10): 2227–34. https://doi.org/10.1007/s40279-018-0953-x.
Bolling, Caroline, Jay Mellette, H Roeline Pasman, Willem van Mechelen, and Evert Verhagen. 2019. “From the Safety Net to the Injury Prevention Web: Applying Systems Thinking to Unravel Injury Prevention Challenges and Opportunities in Cirque Du Soleil.” *BMJ Open Sport & Exercise Medicine* 5 (1): e000492. https://doi.org/10.1136/bmjsem-2018-000492.
Bonnar, Daniel, Kate Bartel, Naomi Kakoschke, and Christin Lang. 2018. “Sleep Interventions Designed to Improve Athletic Performance and Recovery: A Systematic Review of Current Approaches.” *Sports Medicine* 48 (3): 683–703. https://doi.org/10.1007/s40279-017-0832-x.
Bourdon, Pitre C., Marco Cardinale, Andrew Murray, Paul Gastin, Michael Kellmann, Matthew C. Varley, Tim J. Gabbett, et al. 2017. “Monitoring Athlete Training Loads: Consensus Statement.” *International Journal of Sports Physiology and Performance* 12 (s2): S2-161-S2-170. https://doi.org/10.1123/IJSPP.2017-0208.
Bourne, M. N., D. A. Opar, M. D. Williams, A. Al Najjar, and A. J. Shield. 2016. “Muscle Activation Patterns in the Nordic Hamstring Exercise: Impact of Prior Strain Injury: Hamstring Activation in Nordic Exercise.” *Scandinavian Journal of Medicine & Science in Sports* 26 (6): 666–74. https://doi.org/10.1111/sms.12494.
Bourne, Matthew N., Andrea M. Bruder, Benjamin F. Mentiplay, David L. Carey, Brooke E. Patterson, and Kay M. Crossley. 2019. “Eccentric Knee Flexor Weakness in Elite Female Footballers 1–10 Years Following Anterior Cruciate Ligament Reconstruction.” *Physical Therapy in Sport* 37 (May): 144–49. https://doi.org/10.1016/j.ptsp.2019.03.010.
Bourne, Matthew N., David A. Opar, Morgan D. Williams, and Anthony J. Shield. 2015. “Eccentric Knee Flexor Strength and Risk of Hamstring Injuries in Rugby Union: A Prospective Study.” *The American Journal of Sports Medicine* 43 (11): 2663–70. https://doi.org/10.1177/0363546515599633.
Bourne, Matthew N., Chris Pollard, Daniel Messer, Ryan G. Timmins, David A. Opar, Morgan D. Williams, and Anthony J. Shield. 2021. “Hamstring and Gluteal Activation during High-Speed Overground Running: Impact of Prior Strain Injury.” *Journal of Sports Sciences* 39 (18): 2073–79. https://doi.org/10.1080/02640414.2021.1917839.
Bourne, Matthew N, Morgan D Williams, David A Opar, Aiman Al Najjar, Graham K Kerr, and Anthony J Shield. 2017. “Impact of Exercise Selection on Hamstring Muscle Activation.” *British Journal of Sports Medicine* 51 (13): 1021–28. https://doi.org/10.1136/bjsports-2015-095739.
Boyle, Eoghan, Shane Malone, Shane Mangan, Dominic A. Doran, and Kieran Collins. 2022. “Applied Sport Science of Gaelic Football.” *Sport Sciences for Health*, November. https://doi.org/10.1007/s11332-022-01015-x.
Braham, R, C Finch, and P McCrory. 2004. “Non-Participation in Sports Injury Research: Why Football Players Choose Not to Be Involved.” *British Journal of Sports Medicine* 38 (2): 238–39. https://doi.org/10.1136/bjsm.2002.003525.
Bretzin, Abigail C., Jamie L. Mansell, Ryan T. Tierney, and Jane K. McDevitt. 2017. “Sex Differences in Anthropometrics and Heading Kinematics Among Division I

Soccer Athletes: A Pilot Study." *Sports Health: A Multidisciplinary Approach* 9 (2): 168–73. https://doi.org/10.1177/1941738116678615.
Brooks, J H M. 2005. "Epidemiology of Injuries in English Professional Rugby Union: Part 1 Match Injuries." *British Journal of Sports Medicine* 39 (10): 757–66. https://doi.org/10.1136/bjsm.2005.018135.
Brooks, John H M, and Colin W Fuller. 2006. "The Influence of Methodological Issues on the Results and Conclusions from Epidemiological Studies of Sports Injuries: Illustrative Examples." *Sports Medicine* 36 (6): 459–72. https://doi.org/10.2165/00007256-200636060-00001.
Brooks, John H. M., Colin W. Fuller, Simon P. T. Kemp, and Dave B. Reddin. 2006. "Incidence, Risk, and Prevention of Hamstring Muscle Injuries in Professional Rugby Union." *The American Journal of Sports Medicine* 34 (8): 1297–1306. https://doi.org/10.1177/0363546505286022.
Brown, Justin, and Michael Waller. 2014. "Needs Analysis, Physiological Response, and Program Guidelines for Gaelic Football." *Strength & Conditioning Journal* 36 (2): 73–81. https://doi.org/10.1519/SSC.0000000000000045.
Bruder, Andrea M., Kay M. Crossley, Alex Donaldson, and Andrea B. Mosler. 2021. "Through the Athlete Lens: A Novel Study Exploring the Perspectives and Experiences of Injury Prevention Practices in Women Playing Elite Australian Football." *Brazilian Journal of Physical Therapy* 25 (6): 756–66. https://doi.org/10.1016/j.bjpt.2021.05.003.
Bruder, Andrea M., Alex Donaldson, Andrea B. Mosler, Brooke E. Patterson, Melissa Haberfield, Benjamin F. Mentiplay, Patrick Clifton, Nicole D. Livingstone, and Kay M. Crossley. 2021. "Creating Prep to Play PRO for Women Playing Elite Australian Football: A How-to Guide for Developing Injury-Prevention Programs." *Journal of Sport and Health Science*, September, S2095254621001009. https://doi.org/10.1016/j.jshs.2021.09.003.
Buchheit, Martin, Yannick Cholley, Mark Nagel, and Nicholas Poulos. 2016. "The Effect of Body Mass on Eccentric Knee-Flexor Strength Assessed With an Instrumented Nordic Hamstring Device (Nordbord) in Football Players." *International Journal of Sports Physiology and Performance* 11 (6): 721–26. https://doi.org/10.1123/ijspp.2015-0513.
Buckley, Catherine Susan, and Catherine Blake. 2018. "The Incidence of Injury in Elite Camogie, an in-Season Prospective Study." *BMJ Open Sport & Exercise Medicine* 4 (1): e000315. https://doi.org/10.1136/bmjsem-2017-000315.
Buckthorpe, Matthew, Steve Wright, Stewart Bruce-Low, Gianni Nanni, Thomas Sturdy, Aleksander Stephan Gross, Laura Bowen, et al. 2019. "Recommendations for Hamstring Injury Prevention in Elite Football: Translating Research into Practice." *British Journal of Sports Medicine* 53 (7): 449–56. https://doi.org/10.1136/bjsports-2018-099616.
Byrne, Christopher, Craig Twist, and Roger Eston. 2004. "Neuromuscular Function After Exercise-Induced Muscle Damage: Theoretical and Applied Implications." *Sports Medicine* 34 (1): 49–69. https://doi.org/10.2165/00007256-200434010-00005.
Caine, Dennis, and Brett J. Goodwin. 2016. "Risk Factors for Injury in Pediatric and Adolescent Sports." In *Injury in Pediatric and Adolescent Sports*, edited by Dennis Caine and Laura Purcell, 191–203. Contemporary Pediatric and Adolescent Sports Medicine. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-18141-7_14.
Caldwell, Brian P, and Derek M Peters. 2009. "Seasonal Variation in Physiological Fitness of a Semiprofessional Soccer Team." *Journal of Strength and*

Conditioning Research 23 (5): 1370–77. https://doi.org/10.1519/JSC.0b013e3181a4e82f.

Calloway, Sean P., David M. Hardin, Matthew D. Crawford, J. Michael Hardin, Lawrence J. Lemak, Eric Giza, Brian Forsythe, et al. 2019. "Injury Surveillance in Major League Soccer: A 4-Year Comparison of Injury on Natural Grass Versus Artificial Turf Field." *The American Journal of Sports Medicine* 47 (10): 2279–86. https://doi.org/10.1177/0363546519860522.

Cameron, Kenneth L. 2010. "COMMENTARY: Time for a Paradigm Shift in Conceptualizing Risk Factors in Sports Injury Research." *Journal of Athletic Training* 45 (1): 58–60. https://doi.org/10.4085/1062-6050-45.1.58.

Camogie.ie. n.d. *CIPP*. https://camogie.ie/player-information/player-welfare/injury-prevention-programme/.

Carter, Anthony F., and Reinhold Muller. 2008. "A Survey of Injury Knowledge and Technical Needs of Junior Rugby Union Coaches in Townsville (North Queensland)." *Journal of Science and Medicine in Sport* 11 (2): 167–73. https://doi.org/10.1016/j.jsams.2007.01.004.

Castellani, Brian, and Frederic William Hafferty. 2009. *Sociology and Complexity Science: A New Field of Inquiry*. Understanding Complex Systems. Berlin, Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-540-88462-0.

Cerrah, Ali Onur, Elvin Onarici Gungor, Abdullah Ruhi Soylu, and Hayri Ertan. 2014. "Muscular Activation Differences between Professional and Amateur Soccer Players during Countermovement Jump." *Turkish Journal of Sport and Exercise* 16 (2): 51–51. https://doi.org/10.15314/TJSE.201428105.

Chandran, Avinash, Angelo Elmi, Heather Young, and Loretta DiPietro. 2020. "Determinants of Concussion Diagnosis, Symptomology, and Resolution Time in U.S. High School Soccer Players." *Research in Sports Medicine* 28 (1): 42–54. https://doi.org/10.1080/15438627.2019.1590834.

Chumanov, Elizabeth S., Bryan C. Heiderscheit, and Darryl G. Thelen. 2007. "The Effect of Speed and Influence of Individual Muscles on Hamstring Mechanics during the Swing Phase of Sprinting." *Journal of Biomechanics* 40 (16): 3555–62. https://doi.org/10.1016/j.jbiomech.2007.05.026.

Chumanov, Elizabeth S, Bryan C Heiderscheit, and Darryl G Thelen. 2011. "Hamstring Musculotendon Dynamics during Stance and Swing Phases of High Speed Running." *Medicine Science Sports and Exercise* 43 (3): 525–32.

Clarkson, P. M., K. Nosaka, and B. Braun. 1992. "Muscle Function after Exercise-Induced Muscle Damage and Rapid Adaptation." *Medicine and Science in Sports and Exercise* 24 (5): 512–20.

Clarsen, Benjamin, Grethe Myklebust, and Roald Bahr. 2013. "Development and Validation of a New Method for the Registration of Overuse Injuries in Sports Injury Epidemiology: The Oslo Sports Trauma Research Centre (OSTRC) Overuse Injury Questionnaire." *British Journal of Sports Medicine* 47 (8): 495–502. https://doi.org/10.1136/bjsports-2012-091524.

Cohen, Jacob. 1988. *Statistical Power Analysis for the Behavioral Sciences*. 2nd ed. Hillsdale, N.J: L. Erlbaum Associates.

———. 2013. *Statistical Power Analysis for the Behavioral Sciences*. 0 ed. Routledge. https://doi.org/10.4324/9780203771587.

Colby, Marcus J., Brian Dawson, Peter Peeling, Jarryd Heasman, Brent Rogalski, Michael K. Drew, Jordan Stares, Hassane Zouhal, and Leanne Lester. 2017. "Multivariate Modelling of Subjective and Objective Monitoring Data Improve the Detection of Non-Contact Injury Risk in Elite Australian Footballers." *Journal of Science and Medicine in Sport* 20 (12): 1068–74. https://doi.org/10.1016/j.jsams.2017.05.010.

Collins, D. Kieran, Allistair McRobert, James P. Morton, Declan O'Sullivan, and Dominic A. Doran. 2018. "The Work-Rate of Elite Hurling Match-Play." *Journal of Strength and Conditioning Research* 32 (3): 805–11. https://doi.org/10.1519/JSC.0000000000001822.

Corrigan, John, Sinéad O'Keeffe, and Siobhán O'Connor. 2023. "Barriers and Facilitators to Injury Prevention in Ladies Gaelic Football: A Qualitative Study." *Physical Therapy in Sport* 59 (January): 151–61. https://doi.org/10.1016/j.ptsp.2022.12.008.

Cosgrave, Matthew, and Sean Williams. 2019. "The Epidemiology of Concussion in Professional Rugby Union in Ireland." *Physical Therapy in Sport*, no. 35: 99–105.

Coutts, Aaron J., and Rob Duffield. 2010. "Validity and Reliability of GPS Devices for Measuring Movement Demands of Team Sports." *Journal of Science and Medicine in Sport* 13 (1): 133–35. https://doi.org/10.1016/j.jsams.2008.09.015.

Coventry, Molly, Amanda Timler, Andrea B. Mosler, Kylie Russell, Mervyn Travers, Lauren Mitchell OAM, and Myles C. Murphy. 2023. "'I Lied a Little Bit.' A Qualitative Study Exploring the Perspectives of Elite Australian Athletes on Self-Reported Data." *Physical Therapy in Sport* 60 (March): 91–97. https://doi.org/10.1016/j.ptsp.2023.01.009.

Cromwell, F, J Walsh, and J Gormley. 2000. "A Pilot Study Examining Injuries in Elite Gaelic Footballers." *British Journal of Sports Medicine* 34 (2): 104–8. https://doi.org/10.1136/bjsm.34.2.104.

Cross, Kevin M., Kelly K. Gurka, Susan Saliba, Mark Conaway, and Jay Hertel. 2013. "Comparison of Hamstring Strain Injury Rates Between Male and Female Intercollegiate Soccer Athletes." *The American Journal of Sports Medicine* 41 (4): 742–48. https://doi.org/10.1177/0363546513475342.

Crowley, J., J. Jordan, and E. Falvey. 2011. "A Comparison of Gaelic Football Injuries in Males and Females in Primary Care." *Irish Medical Journal* 104 (9): 268–70.

Cumps, E, E Verhagen, L Annemans, and R Meeusen. 2008. "Injury Rate and Socioeconomic Costs Resulting from Sports Injuries in Flanders: Data Derived from Sports Insurance Statistics 2003." *British Journal of Sports Medicine* 42 (9): 767–72. https://doi.org/10.1136/bjsm.2007.037937.

Curtis, Gannon L., Morad Chughtai, Anton Khlopas, Jared M. Newman, Rafay Khan, Shervin Shaffiy, Ali Nadhim, Anil Bhave, and Michael A. Mont. 2017. "Impact of Physical Activity in Cardiovascular and Musculoskeletal Health: Can Motion Be Medicine?" *Journal of Clinical Medicine Research* 9 (5): 375–81. https://doi.org/10.14740/jocmr3001w.

Cuthbert, Matthew, Nicholas Ripley, John J. McMahon, Martin Evans, G. Gregory Haff, and Paul Comfort. 2020. "The Effect of Nordic Hamstring Exercise Intervention Volume on Eccentric Strength and Muscle Architecture Adaptations: A Systematic Review and Meta-Analyses." *Sports Medicine* 50 (1): 83–99. https://doi.org/10.1007/s40279-019-01178-7.

Dahmane, Raja, Srdjan Djordjevič, and Vika Smerdu. 2006. "Adaptive Potential of Human Biceps Femoris Muscle Demonstrated by Histochemical, Immunohistochemical and Mechanomyographical Methods." *Medical & Biological Engineering & Computing* 44 (11): 999–1006. https://doi.org/10.1007/s11517-006-0114-5.

Daly, Lorcan S., Ciarán Ó Catháin, and David T. Kelly. 2020. “Gaelic Football Match-Play: Performance Attenuation and Timeline of Recovery.” *Sports* 8 (12): 166. https://doi.org/10.3390/sports8120166.
Daly, Lorcan S., Ciarán Ó Catháin, and David T. Kelly. 2022. “Does Physical Conditioning Influence Performance Attenuation and Recovery in Gaelic Football?” *International Journal of Sports Physiology and Performance* 17 (6): 862–70. https://doi.org/10.1123/ijspp.2021-0342.
Danielsson, Adam, Alexandra Horvath, Carl Senorski, Eduard Alentorn-Geli, William E. Garrett, Ramón Cugat, Kristian Samuelsson, and Eric Hamrin Senorski. 2020. “The Mechanism of Hamstring Injuries – a Systematic Review.” *BMC Musculoskeletal Disorders* 21 (1): 641. https://doi.org/10.1186/s12891-020-03658-8.
De Maeseneer, Michel, Maryam Shahabpour, Leon Lenchik, Annemieke Milants, Filip De Ridder, Johan De Mey, and Erik Cattrysse. 2014. “Distal Insertions of the Semimembranosus Tendon: MR Imaging with Anatomic Correlation.” *Skeletal Radiology*, February. https://doi.org/10.1007/s00256-014-1830-9.
De Ste Croix, Mark, F. Ayala, S. Hernandez Sanchez, M. Lehnert, and J. Hughes. 2020. “Grass-Root Coaches Knowledge, Understanding, Attitude And Confidence to Deliver Injury Prevention Training in Youth Soccer: A Comparison of Coaches in Three EU Countries.” *Journal of Science in Sport and Exercise* 2 (4): 367–74. https://doi.org/10.1007/s42978-020-00075-0.
Dekkers, Thomas, Kieran O’Sullivan, Catherine Blake, Joseph G. McVeigh, and Kieran Collins. 2022. “Epidemiology and Moderators of Injury in Gaelic Football: A Systematic Review and Meta-Analysis.” *Journal of Science and Medicine in Sport* 25 (3): 222–29. https://doi.org/10.1016/j.jsams.2021.10.003.
Delecroix, Barthelemy, Alan McCall, Brian Dawson, Serge Berthoin, and Gregory Dupont. 2018. “Workload and Non-Contact Injury Incidence in Elite Football Players Competing in European Leagues.” *European Journal of Sport Science* 18 (9): 1280–87. https://doi.org/10.1080/17461391.2018.1477994.
Delextrat, Anne, Jessica Piquet, Martyn J. Matthews, and Daniel D. Cohen. 2018. “Strength-Endurance Training Reduces the Hamstrings Strength Decline Following Simulated Football Competition in Female Players.” *Frontiers in Physiology* 9 (August): 1059. https://doi.org/10.3389/fphys.2018.01059.
Dick, Randall, Margot Putukian, Julie Agel, Todd A Evans, and Stephen W Marshall. 2007. “Descriptive Epidemiology of Collegiate Women’s Soccer Injuries: National Collegiate Athletic Association Injury Surveillance System, 1988–1989 Through 2002–2003.” *Journal of Athletic Training* 42 (2): 278–85.
DiStefano, Lindsay J., Catie L. Dann, Cindy J. Chang, Margot Putukian, Lauren A. Pierpoint, Dustin W. Currie, Sarah B. Knowles, et al. 2018. “The First Decade of Web-Based Sports Injury Surveillance: Descriptive Epidemiology of Injuries in US High School Girls’ Soccer (2005–2006 Through 2013–2014) and National Collegiate Athletic Association Women’s Soccer (2004–2005 Through 2013–2014).” *Journal of Athletic Training* 53 (9): 880–92. https://doi.org/10.4085/1062-6050-156-17.
Dix, Celeste, David Logerstedt, Amelia Arundale, and Lynn Snyder-Mackler. 2021. “Perceived Barriers to Implementation of Injury Prevention Programs among Collegiate Women’s Soccer Coaches.” *Journal of Science and Medicine in Sport* 24 (4): 352–56. https://doi.org/10.1016/j.jsams.2020.09.016.
Dobrosielski, Devon A., Lisa Sweeney, and Peter J. Lisman. 2021. “The Association Between Poor Sleep and the Incidence of Sport and Physical Training-Related

Injuries in Adult Athletic Populations: A Systematic Review." *Sports Medicine* 51 (4): 777–93. https://doi.org/10.1007/s40279-020-01416-3.
Does, H. van der, M. Brink, A. Benjaminse, C. Visscher, and K. Lemmink. 2015. "Jump Landing Characteristics Predict Lower Extremity Injuries in Indoor Team Sports." *International Journal of Sports Medicine* 37 (03): 251–56. https://doi.org/10.1055/s-0035-1559688.
Doherty, Cailbhe, Chris Bleakley, Jay Hertel, Brian Caulfield, John Ryan, and Eamonn Delahunt. 2015. "Lower Extremity Function during Gait in Participants with First Time Acute Lateral Ankle Sprain Compared to Controls." *Journal of Electromyography and Kinesiology* 25 (1): 182–92. https://doi.org/10.1016/j.jelekin.2014.09.004.
Donaldson, A, and Cf Finch. 2012. "Planning for Implementation and Translation: Seek First to Understand the End-Users' Perspectives." *British Journal of Sports Medicine* 46 (5): 306–7. https://doi.org/10.1136/bjsports-2011-090461.
Donaldson, Alex, Aisling Callaghan, Mario Bizzini, Andrew Jowett, Patrick Keyzer, and Matthew Nicholson. 2018. "Awareness and Use of the 11+ Injury Prevention Program among Coaches of Adolescent Female Football Teams." *International Journal of Sports Science & Coaching* 13 (6): 929–38. https://doi.org/10.1177/1747954118787654.
Donaldson, Alex, and Caroline F Finch. 2013. "Applying Implementation Science to Sports Injury Prevention." *British Journal of Sports Medicine* 47 (8): 473–75. https://doi.org/10.1136/bjsports-2013-092323.
Donaldson, Alex, David G Lloyd, Belinda J Gabbe, Jill Cook, and Caroline F Finch. 2017. "We Have the Programme, What next? Planning the Implementation of an Injury Prevention Programme." *Injury Prevention* 23 (4): 273–80. https://doi.org/10.1136/injuryprev-2015-041737.
Drew, Michael K, Jill Cook, and Caroline F Finch. 2016. "Sports-Related Workload and Injury Risk: Simply Knowing the Risks Will Not Prevent Injuries: Narrative Review." *British Journal of Sports Medicine* 50 (21): 1306–8. https://doi.org/10.1136/bjsports-2015-095871.
Duggan, John David, Jeremy Moody, Paul J. Byrne, and Lisa Ryan. 2020. "Strength and Conditioning Recommendations for Female GAA Athletes: The Camogie Player." *Strength & Conditioning Journal* 42 (4): 105–24. https://doi.org/10.1519/SSC.0000000000000577.
Duhig, Steven, Anthony J Shield, David Opar, Tim J Gabbett, Cameron Ferguson, and Morgan Williams. 2016. "Effect of High-Speed Running on Hamstring Strain Injury Risk." *British Journal of Sports Medicine* 50 (24): 1536–40. https://doi.org/10.1136/bjsports-2015-095679.
Durlak, Joseph A., and Emily P. DuPre. 2008. "Implementation Matters: A Review of Research on the Influence of Implementation on Program Outcomes and the Factors Affecting Implementation." *American Journal of Community Psychology* 41 (3–4): 327–50. https://doi.org/10.1007/s10464-008-9165-0.
Dyk, Nicol van, Roald Bahr, Angus F Burnett, Rod Whiteley, Arnhild Bakken, Andrea Mosler, Abdulaziz Farooq, and Erik Witvrouw. 2017. "A Comprehensive Strength Testing Protocol Offers No Clinical Value in Predicting Risk of Hamstring Injury: A Prospective Cohort Study of 413 Professional Football Players." *British Journal of Sports Medicine* 51 (23): 1695–1702. https://doi.org/10.1136/bjsports-2017-097754.
Dyk, Nicol van, Roald Bahr, Rodney Whiteley, Johannes L. Tol, Bhavesh D. Kumar, Bruce Hamilton, Abdulaziz Farooq, and Erik Witvrouw. 2016. "Hamstring and

Quadriceps Isokinetic Strength Deficits Are Weak Risk Factors for Hamstring Strain Injuries: A 4-Year Cohort Study.” *The American Journal of Sports Medicine* 44 (7): 1789–95. https://doi.org/10.1177/0363546516632526.
Dyk, Nicol van, Fearghal P Behan, and Rod Whiteley. 2019. “Including the Nordic Hamstring Exercise in Injury Prevention Programmes Halves the Rate of Hamstring Injuries: A Systematic Review and Meta-Analysis of 8459 Athletes.” *British Journal of Sports Medicine* 53 (21): 1362–70. https://doi.org/10.1136/bjsports-2018-100045.
Dyk, Nicol van, Abdulaziz Farooq, Roald Bahr, and Erik Witvrouw. 2018. “Hamstring and Ankle Flexibility Deficits Are Weak Risk Factors for Hamstring Injury in Professional Soccer Players: A Prospective Cohort Study of 438 Players Including 78 Injuries.” *The American Journal of Sports Medicine* 46 (9): 2203–10. https://doi.org/10.1177/0363546518773057.
Ebben, William P, and Erich J Petushek. 2010. “Using the Reactive Strength Index Modified to Evaluate Plyometric Performance.” *Journal of Strength and Conditioning Research* 24 (8): 1983–87. https://doi.org/10.1519/JSC.0b013e3181e72466.
Edouard, Pascal, and Kevin R. Ford. 2020. “Great Challenges Toward Sports Injury Prevention and Rehabilitation.” *Frontiers in Sports and Active Living* 2 (July): 80. https://doi.org/10.3389/fspor.2020.00080.
Edouard, Pascal, Philippe Gimenez, Pierrick Arnal, Pedro Jimenez-Reyes, Pierre Samozino, Mendiguchia Jurdan, Matt Brughelli, and Jean-Benoît Morin. 2017. “INFLUENCE OF FATIGUE ON HAMSTRING MUSCLE FUNCTION DURING REPEATED SPRINTS.” *British Journal of Sports Medicine* 51 (4): 314.2-314. https://doi.org/10.1136/bjsports-2016-097372.79.
Edouard, Pascal, Jurdan Mendiguchia, Kenny Guex, Johan Lahti, Pierre Samozino, and Jean-Benoıt Morin. 2019. “Sprinting: A Potential Vaccine for Hamstring Injury?” *Science Performance and Science Reports* 1: 1–2.
Edwards, W. Brent. 2018. “Modeling Overuse Injuries in Sport as a Mechanical Fatigue Phenomenon.” *Exercise and Sport Sciences Reviews* 46 (4): 224–31. https://doi.org/10.1249/JES.0000000000000163.
Egan, Brendan, Damien Young, Kieran Collins, Shane Malone, and Giuseppe Coratella. 2021. “The Between-Competition Running Demands of Elite Hurling Match-Play.” *Sports* 9 (11): 145. https://doi.org/10.3390/sports9110145.
Ekstrand, Jan, Håkan Bengtsson, Markus Waldén, Michael Davison, Karim M Khan, and Martin Hägglund. 2023. “Hamstring Injury Rates Have Increased during Recent Seasons and Now Constitute 24% of All Injuries in Men’s Professional Football: The UEFA Elite Club Injury Study from 2001/02 to 2021/22.” *British Journal of Sports Medicine* 57 (5): 292–98. https://doi.org/10.1136/bjsports-2021-105407.
Ekstrand, Jan, Jeremiah C Healy, Markus Waldén, Justin C Lee, Bryan English, and Martin Hägglund. 2012. “Hamstring Muscle Injuries in Professional Football: The Correlation of MRI Findings with Return to Play.” *British Journal of Sports Medicine* 46 (2): 112–17. https://doi.org/10.1136/bjsports-2011-090155.
Ekstrand, Jan, Armin Spreco, Håkan Bengtsson, and Roald Bahr. 2021. “Injury Rates Decreased in Men’s Professional Football: An 18-Year Prospective Cohort Study of Almost 12 000 Injuries Sustained during 1.8 Million Hours of Play.” *British Journal of Sports Medicine* 55 (19): 1084–92. https://doi.org/10.1136/bjsports-2020-103159.
Ekstrand, Jan, Markus Waldén, and Martin Hägglund. 2016. “Hamstring Injuries Have Increased by 4% Annually in Men’s Professional Football, since 2001: A 13-Year

Longitudinal Analysis of the UEFA Elite Club Injury Study.” *British Journal of Sports Medicine* 50 (12): 731–37. https://doi.org/10.1136/bjsports-2015-095359.
Emery, Carolyn A, Brent Hagel, and Barbara A Morrongiello. 2006. “Injury Prevention in Child and Adolescent Sport: Whose Responsibility Is It?” *Clinical Journal of Sport Medicine* 16 (6): 514–21. https://doi.org/10.1097/01.jsm.0000251179.90840.58.
Emery, Carolyn A., and Kati Pasanen. 2019. “Current Trends in Sport Injury Prevention.” *Best Practice & Research Clinical Rheumatology* 33 (1): 3–15. https://doi.org/10.1016/j.berh.2019.02.009.
Erickson, Lauren N., and Marc A. Sherry. 2017. “Rehabilitation and Return to Sport after Hamstring Strain Injury.” *Journal of Sport and Health Science* 6 (3): 262–70. https://doi.org/10.1016/j.jshs.2017.04.001.
Finch, C. 2002. “Safety Attitudes and Beliefs of Junior Australian Football Players.” *Injury Prevention* 8 (2): 151–54. https://doi.org/10.1136/ip.8.2.151.
Finch, C. F. 2011. “No Longer Lost in Translation: The Art and Science of Sports Injury Prevention Implementation Research.” *British Journal of Sports Medicine* 45 (16): 1253–57. https://doi.org/10.1136/bjsports-2011-090230.
Finch, C. F., and A. Donaldson. 2010. “A Sports Setting Matrix for Understanding the Implementation Context for Community Sport.” *British Journal of Sports Medicine* 44 (13): 973–78. https://doi.org/10.1136/bjsm.2008.056069.
Finch, Caroline. 2006a. “A New Framework for Research Leading to Sports Injury Prevention.” *Journal of Science and Medicine in Sport* 9 (1–2): 3–9. https://doi.org/10.1016/j.jsams.2006.02.009.
———. 2006b. “A New Framework for Research Leading to Sports Injury Prevention.” *Journal of Science and Medicine in Sport* 9 (1–2): 3–9. https://doi.org/10.1016/j.jsams.2006.02.009.
Finch, Caroline F. 1997. “An Overview of Some Definitional Issues for Sports Injury Surveillance:” *Sports Medicine* 24 (3): 157–63. https://doi.org/10.2165/00007256-199724030-00002.
Finch, Caroline F, Kathy Diamantopoulou, Dara M Twomey, Tim L A Doyle, David G Lloyd, Warren Young, and Bruce C Elliott. 2014. “The Reach and Adoption of a Coach-Led Exercise Training Programme in Community Football.” *British Journal of Sports Medicine* 48 (8): 718–23. https://doi.org/10.1136/bjsports-2012-091797.
Fokkema, Tryntsje, Robert-Jan de Vos, Sita M.A. Bierma-Zeinstra, and Marienke van Middelkoop. 2019. “Opinions, Barriers, and Facilitators of Injury Prevention in Recreational Runners.” *Journal of Orthopaedic & Sports Physical Therapy* 49 (10): 736–42. https://doi.org/10.2519/jospt.2019.9029.
Fortington, Lauren V, Alex Donaldson, and Caroline F Finch. 2016. “Self-Reported Worst Injuries in Women’s Australian Football Identify Lower Limb Injuries as a Prevention Priority.” *BMJ Open Sport & Exercise Medicine* 2 (1): e000112. https://doi.org/10.1136/bmjsem-2016-000112.
Fousekis, K., E. Tsepis, P. Poulmedis, S. Athanasopoulos, and G. Vagenas. 2011. “Intrinsic Risk Factors of Non-Contact Quadriceps and Hamstring Strains in Soccer: A Prospective Study of 100 Professional Players.” *British Journal of Sports Medicine* 45 (9): 709–14. https://doi.org/10.1136/bjsm.2010.077560.
Fox, Domhnaill, Edwenia O’Malley, and Catherine Blake. 2014. “Normative Data for the Functional Movement Screen^{TM} in Male Gaelic Field Sports.” *Physical Therapy in Sport* 15 (3): 194–99. https://doi.org/10.1016/j.ptsp.2013.11.004.

Freckleton, Grant, and Tania Pizzari. 2013. "Risk Factors for Hamstring Muscle Strain Injury in Sport: A Systematic Review and Meta-Analysis." *British Journal of Sports Medicine* 47 (6): 351–58. https://doi.org/10.1136/bjsports-2011-090664.

Fuller, C. W., J. Ekstrand, A. Junge, T. E. Andersen, R. Bahr, J. Dvorak, M. Hagglund, P. McCrory, and W. H. Meeuwisse. 2006. "Consensus Statement on Injury Definitions and Data Collection Procedures in Studies of Football (Soccer) Injuries." *Scandinavian Journal of Medicine and Science in Sports* 16 (2): 83–92. https://doi.org/10.1111/j.1600-0838.2006.00528.x.

Fyfe, Jackson J., David A. Opar, Morgan D. Williams, and Anthony J. Shield. 2013. "The Role of Neuromuscular Inhibition in Hamstring Strain Injury Recurrence." *Journal of Electromyography and Kinesiology* 23 (3): 523–30. https://doi.org/10.1016/j.jelekin.2012.12.006.

GAA.ie. n.d. https://learning.gaa.ie/gaa15.

Gabbe, B J. 2005. "Risk Factors for Hamstring Injuries in Community Level Australian Football." *British Journal of Sports Medicine* 39 (2): 106–10. https://doi.org/10.1136/bjsm.2003.011197.

Gabbe, B. J., K. L. Bennell, C. F. Finch, H. Wajswelner, and J. W. Orchard. 2006. "Predictors of Hamstring Injury at the Elite Level of Australian Football." *Scandinavian Journal of Medicine and Science in Sports* 16 (1): 7–13. https://doi.org/10.1111/j.1600-0838.2005.00441.x.

Gabbe, B J, C Finch, K Bennell, and H. Wajswelner. 2003. "How Valid Is a Self Reported 12 Month Sports Injury History?" *British Journal of Sports Medicine* 37 (6): 545–47. https://doi.org/10.1136/bjsm.37.6.545.

Gabbett, Tim J. 2016. "The Training—Injury Prevention Paradox: Should Athletes Be Training Smarter *and* Harder?" *British Journal of Sports Medicine* 50 (5): 273–80. https://doi.org/10.1136/bjsports-2015-095788.

Gabbett, Tim J., and Shahid Ullah. 2012. "Relationship Between Running Loads and Soft-Tissue Injury in Elite Team Sport Athletes." *The Journal of Strength & Conditioning Research* 26 (4): 953–60. https://doi.org/10.1519/JSC.0b013e3182302023.

Gaglio, Bridget, Jo Ann Shoup, and Russell E. Glasgow. 2013. "The RE-AIM Framework: A Systematic Review of Use Over Time." *American Journal of Public Health* 103 (6): e38–46. https://doi.org/10.2105/AJPH.2013.301299.

Garrett, Joel, Stuart R. Graham, Roger G. Eston, Darren J. Burgess, Lachlan J. Garrett, John Jakeman, and Kevin Norton. 2019. "A Novel Method of Assessment for Monitoring Neuromuscular Fatigue in Australian Rules Football Players." *International Journal of Sports Physiology and Performance* 14 (5): 598–605. https://doi.org/10.1123/ijspp.2018-0253.

Garrett, W. E. 1990. "Muscle Strain Injuries: Clinical and Basic Aspects." *Medicine and Science in Sports and Exercise* 22 (4): 436–43.

———. 1996. "Muscle Strain Injuries." *The American Journal of Sports Medicine* 24 (6 Suppl): S2-8.

Green, Brady, Matthew N Bourne, Nicol van Dyk, and Tania Pizzari. 2020. "Recalibrating the Risk of Hamstring Strain Injury (HSI): A 2020 Systematic Review and Meta-Analysis of Risk Factors for Index and Recurrent Hamstring Strain Injury in Sport." *British Journal of Sports Medicine* 54 (18): 1081–88. https://doi.org/10.1136/bjsports-2019-100983.

Green, Brady, Matthew N Bourne, and Tania Pizzari. 2018. "Isokinetic Strength Assessment Offers Limited Predictive Validity for Detecting Risk of Future Hamstring Strain in Sport: A Systematic Review and Meta-Analysis." *British*

Journal of Sports Medicine 52 (5): 329–36. https://doi.org/10.1136/bjsports-2017-098101.
Griffin, Alan, Ian C. Kenny, Thomas M. Comyns, and Mark Lyons. 2020. "The Association Between the Acute:Chronic Workload Ratio and Injury and Its Application in Team Sports: A Systematic Review." *Sports Medicine* 50 (3): 561–80. https://doi.org/10.1007/s40279-019-01218-2.
Gronwald, Thomas, Christian Klein, Tim Hoenig, Micha Pietzonka, Hendrik Bloch, Pascal Edouard, and Karsten Hollander. 2021. "Hamstring Injury Patterns in Professional Male Football (Soccer): A Systematic Video Analysis of 52 Cases." *British Journal of Sports Medicine*, December, bjsports-2021-104769. https://doi.org/10.1136/bjsports-2021-104769.
Hagel, Brent. 2005. "Hamstring Injuries in Australian Football:" *Clinical Journal of Sport Medicine* 15 (5): 400. https://doi.org/10.1097/01.jsm.0000179227.01404.d3.
Hägglund, M, M Waldén, R. Bahr, and J Ekstrand. 2005. "Methods for Epidemiological Study of Injuries to Professional Football Players: Developing the UEFA Model." *British Journal of Sports Medicine* 39 (6): 340–46. https://doi.org/10.1136/bjsm.2005.018267.
Hägglund, M., M Waldén, and J. Ekstrand. 2009. "Injuries among Male and Female Elite Football Players." *Scandinavian Journal of Medicine & Science in Sports* 19 (6): 819–27. https://doi.org/10.1111/j.1600-0838.2008.00861.x.
Hägglund, Martin, Markus Waldén, and Jan Ekstrand. 2016. "Injury Recurrence Is Lower at the Highest Professional Football Level than at National and Amateur Levels: Does Sports Medicine and Sports Physiotherapy Deliver?" *British Journal of Sports Medicine* 50 (12): 751–58. https://doi.org/10.1136/bjsports-2015-095951.
Hägglund, Martin, Markus Waldén, Henrik Magnusson, Karolina Kristenson, Håkan Bengtsson, and Jan Ekstrand. 2013. "Injuries Affect Team Performance Negatively in Professional Football: An 11-Year Follow-up of the UEFA Champions League Injury Study." *British Journal of Sports Medicine* 47 (12): 738–42. https://doi.org/10.1136/bjsports-2013-092215.
Hamner, Samuel R., and Scott L. Delp. 2013. "Muscle Contributions to Fore-Aft and Vertical Body Mass Center Accelerations over a Range of Running Speeds." *Journal of Biomechanics* 46 (4): 780–87. https://doi.org/10.1016/j.jbiomech.2012.11.024.
Hanson, Dale, John P Allegrante, David A Sleet, and Caroline F Finch. 2014. "Research Alone Is Not Sufficient to Prevent Sports Injury." *British Journal of Sports Medicine* 48 (8): 682–84. https://doi.org/10.1136/bjsports-2012-091434.
Hanson, Dale W., Caroline F. Finch, John P. Allegrante, and David Sleet. 2012. "Closing the Gap between Injury Prevention Research and Community Safety Promotion Practice: Revisiting the Public Health Model." *Public Health Reports (Washington, D.C.: 1974)* 127 (2): 147–55. https://doi.org/10.1177/003335491212700203.
Harding, Amy T, Benjamin Kurt Weeks, Sean A Horan, Andrew Little, Steven L Watson, and Belinda Ruth Beck. 2017. "Validity and Test–Retest Reliability of a Novel Simple Back Extensor Muscle Strength Test." *SAGE Open Medicine* 5 (December): 205031211668884. https://doi.org/10.1177/2050312116688842.
Harøy, Joar, Benjamin Clarsen, Espen Guldahl Wiger, Mari Glomnes Øyen, Andreas Serner, Kristian Thorborg, Per Hölmich, Thor Einar Andersen, and Roald Bahr. 2019. "The Adductor Strengthening Programme Prevents Groin Problems among Male Football Players: A Cluster-Randomised Controlled Trial." *British Journal of Sports Medicine* 53 (3): 150–57. https://doi.org/10.1136/bjsports-2017-098937.

Hasan, Laith K, Tara Shelby, Ioanna K Bolia, Timothy Chu, Nicholas Trasolini, Francisco A Padilla, Brandon Levian, et al. 2023. “Incidence of Injuries among Lacrosse Athletes: A Systematic Review and Meta-Analysis.” *The Physician and Sportsmedicine* 51 (2): 158–65. https://doi.org/10.1080/00913847.2021.2020601.

Hashemi, J., N. Chandrashekar, T. Jang, F. Karpat, M. Oseto, and S. Ekwaro-Osire. 2007. “An Alternative Mechanism of Non-Contact Anterior Cruciate Ligament Injury During Jump-Landing: In-Vitro Simulation.” *Experimental Mechanics* 47 (3): 347–54. https://doi.org/10.1007/s11340-007-9043-y.

Hausken-Sutter, Solveig Elisabeth, Klara Boije Af Gennäs, Astrid Schubring, Stefan Grau, Jonatan Jungmalm, and Natalie Barker-Ruchti. 2022. “Integrating Qualitative and Quantitative Data in Sport Injury Research: An Interdisciplinary Procedure.” Preprint. In Review. https://doi.org/10.21203/rs.3.rs-2185664/v1.

Hausken-Sutter, Solveig Elisabeth, Richard Pringle, Astrid Schubring, Stefan Grau, and Natalie Barker-Ruchti. 2021. “Youth Sport Injury Research: A Narrative Review and the Potential of Interdisciplinarity.” *BMJ Open Sport & Exercise Medicine* 7 (1): e000933. https://doi.org/10.1136/bmjsem-2020-000933.

Heiderscheit, Bryan C., Dina M. Hoerth, Elizabeth S. Chumanov, Stephen C. Swanson, Brian J. Thelen, and Darryl G. Thelen. 2005. “Identifying the Time of Occurrence of a Hamstring Strain Injury during Treadmill Running: A Case Study.” *Clinical Biomechanics* 20 (10): 1072–78. https://doi.org/10.1016/j.clinbiomech.2005.07.005.

Heiderscheit, Bryan C., Marc A. Sherry, Amy Silder, Elizabeth S. Chumanov, and Darryl G. Thelen. 2010. “Hamstring Strain Injuries: Recommendations for Diagnosis, Rehabilitation, and Injury Prevention.” *Journal of Orthopaedic & Sports Physical Therapy* 40 (2): 67–81. https://doi.org/10.2519/jospt.2010.3047.

Heishman, Aaron, Brady Brown, Bryce Daub, Ryan Miller, Eduardo Freitas, and Michael Bemben. 2019. “The Influence of Countermovement Jump Protocol on Reactive Strength Index Modified and Flight Time: Contraction Time in Collegiate Basketball Players.” *Sports* 7 (2): 37. https://doi.org/10.3390/sports7020037.

Henderson, Gary, Christopher A. Barnes, and Matthew D. Portas. 2010. “Factors Associated with Increased Propensity for Hamstring Injury in English Premier League Soccer Players.” *Journal of Science and Medicine in Sport* 13 (4): 397–402. https://doi.org/10.1016/j.jsams.2009.08.003.

Hickey, Jack T., David A. Opar, Leigh J. Weiss, and Bryan C. Heiderscheit. 2022. “Hamstring Strain Injury Rehabilitation.” *Journal of Athletic Training* 57 (2): 125–35. https://doi.org/10.4085/1062-6050-0707.20.

Higashihara, Ayako, Takashi Ono, Gaku Tokutake, Rieko Kuramochi, Yasuhiro Kunita, Yasuharu Nagano, and Norikazu Hirose. 2019. “Hamstring Muscles’ Function Deficit during Overground Sprinting in Track and Field Athletes with a History of Strain Injury.” *Journal of Sports Sciences* 37 (23): 2744–50. https://doi.org/10.1080/02640414.2019.1664030.

Hinton, Richard Y., Andrew E. Lincoln, Jon L. Almquist, Wiemi A. Douoguih, and Krishn M. Sharma. 2005. “Epidemiology of Lacrosse Injuries in High School-Aged Girls and Boys: A 3-Year Prospective Study.” *The American Journal of Sports Medicine* 33 (9): 1305–14. https://doi.org/10.1177/0363546504274148.

Hoffman, Daniel Tyler, Dan Brian Dwyer, Steven J Bowe, Patrick Clifton, and Paul B Gastin. 2020. “Is Injury Associated with Team Performance in Elite Australian Football? 20 Years of Player Injury and Team Performance Data That Include Measures of Individual Player Value.” *British Journal of Sports Medicine* 54 (8): 475–79. https://doi.org/10.1136/bjsports-2018-100029.

Horgan, Peter, Richard Bowles, John Considine, Paul Donnelly, William Harmon, Hayley Harrison, Seamus Kelly, et al. 2021. "Coaching and Coach Education in Gaelic Games: A Baseline Report." https://www.gaa.ie/news/gaelic-games-to-benefit-from-lessons-of-coaching-survey/.

Horst, Nick van der, Fjg Backx, Edwin A Goedhart, and Bionka MA Huisstede. 2017. "Return to Play after Hamstring Injuries in Football (Soccer): A Worldwide Delphi Procedure Regarding Definition, Medical Criteria and Decision-Making." *British Journal of Sports Medicine* 51 (22): 1583–91. https://doi.org/10.1136/bjsports-2016-097206.

Hreljac, Alan. 2005. "Etiology, Prevention, and Early Intervention of Overuse Injuries in Runners: A Biomechanical Perspective." *Physical Medicine and Rehabilitation Clinics of North America* 16 (3): 651–67. https://doi.org/10.1016/j.pmr.2005.02.002.

Hübscher, Markus, Astrid Zech, Klaus Pfeifer, Frank Hänsel, Lutz Vogt, and Winfried Banzer. 2010. "Neuromuscular Training for Sports Injury Prevention: A Systematic Review." *Medicine & Science in Sports & Exercise* 42 (3): 413–21. https://doi.org/10.1249/MSS.0b013e3181b88d37.

Hulme, A., P.M. Salmon, R.O. Nielsen, G.J.M. Read, and C.F. Finch. 2017. "From Control to Causation: Validating a 'Complex Systems Model' of Running-Related Injury Development and Prevention." *Applied Ergonomics* 65 (November): 345–54. https://doi.org/10.1016/j.apergo.2017.07.005.

Hulme, Adam, and Caroline F. Finch. 2016. "The Epistemic Basis of Distance Running Injury Research: A Historical Perspective." *Journal of Sport and Health Science* 5 (2): 172–75. https://doi.org/10.1016/j.jshs.2016.01.023.

Huston, Laura J., and Edward M. Wojtys. 1996. "Neuromuscular Performance Characteristics in Elite Female Athletes." *The American Journal of Sports Medicine* 24 (4): 427–36. https://doi.org/10.1177/036354659602400405.

Ireland, Mary Lloyd. 2002. "The Female ACL: Why Is It More Prone to Injury?" *Orthopedic Clinics of North America* 33 (4): 637–51. https://doi.org/10.1016/S0030-5898(02)00028-7.

Jeanguyot, Evan, Benjamin Salcinovic, Amanda Johnson, Nicol van Dyk, and Rod Whiteley. 2023. "Eccentric Hamstring Strength in Young Athletes Is Best Documented When Normalised to Body Mass: A Cross-Sectional Study with Normative Data of 590 Athletes from Different Age Categories." *Biology of Sport*. https://doi.org/10.5114/biolsport.2023.125585.

Jensen, Jesper, Per Hölmich, Thomas Bandholm, Mette K Zebis, Lars L Andersen, and Kristian Thorborg. 2014. "Eccentric Strengthening Effect of Hip-Adductor Training with Elastic Bands in Soccer Players: A Randomised Controlled Trial." *British Journal of Sports Medicine* 48 (4): 332–38. https://doi.org/10.1136/bjsports-2012-091095.

Johnston, Rich D., Tim J. Gabbett, David G. Jenkins, and Billy T. Hulin. 2015. "Influence of Physical Qualities on Post-Match Fatigue in Rugby League Players." *Journal of Science and Medicine in Sport* 18 (2): 209–13. https://doi.org/10.1016/j.jsams.2014.01.009.

Kalkhoven, Judd T., Mark L. Watsford, and Franco M. Impellizzeri. 2020. "A Conceptual Model and Detailed Framework for Stress-Related, Strain-Related, and Overuse Athletic Injury." *Journal of Science and Medicine in Sport* 23 (8): 726–34. https://doi.org/10.1016/j.jsams.2020.02.002.

Keller, Karsten, and Martin Engelhardt. 2013. “Strength and Muscle Mass Loss with Aging Process. Age and Strength Loss.” *Muscles, Ligaments and Tendons Journal* 3 (4): 346–50.
Kellis, Eleftherios, and Chrysostomos Sahinis. 2022. “Is Muscle Architecture Different in Athletes with a Previous Hamstring Strain? A Systematic Review and Meta-Analysis.” *Journal of Functional Morphology and Kinesiology* 7 (1): 16. https://doi.org/10.3390/jfmk7010016.
Kelly, Elish, Joanne Banks, Seamus McGuinness, and Dorothy Watson. 2018. “Playing Senior Inter-County Gaelic Games: Experiences, Realities and Consequences.” ESRI. https://doi.org/10.26504/rs76.
Kelly, Glen, Odharnaith McKenna, Sharon Courtney, Kieran Collins, Jonathan Bradley, and Denise Martin. 2022. “Benchmarking Successful Performances in Elite Ladies Gaelic Football.” *International Journal of Performance Analysis in Sport* 22 (1): 51–65. https://doi.org/10.1080/24748668.2021.2020031.
Kelly, Sean T., and Clare A. Lodge. 2018. “Effects of the GAA15 in Reducing Lower Extremity Injury Rates in Adolescent Males Participating in Hurling.” *Physiotherapy Practice and Research* 39 (2): 99–105. https://doi.org/10.3233/PPR-180112.
Kenneally-Dabrowski, Claire J. B., Nicholas A. T. Brown, Adrian K. M. Lai, Diana Perriman, Wayne Spratford, and Benjamin G. Serpell. 2019. “Late Swing or Early Stance? A Narrative Review of Hamstring Injury Mechanisms during High-speed Running.” *Scandinavian Journal of Medicine & Science in Sports* 29 (8): 1083–91. https://doi.org/10.1111/sms.13437.
Kerr, H A, C Curtis, L J Micheli, M S Kocher, D Zurakowski, S P T Kemp, and J H M Brooks. 2008. “Collegiate Rugby Union Injury Patterns in New England: A Prospective Cohort Study.” *British Journal of Sports Medicine* 42 (7): 595–603. https://doi.org/10.1136/bjsm.2007.035881.
Kerr, Zachary Y., Margot Putukian, Cindy J. Chang, Lindsay J. DiStefano, Dustin W. Currie, Lauren A. Pierpoint, Sarah B. Knowles, et al. 2018. “The First Decade of Web-Based Sports Injury Surveillance: Descriptive Epidemiology of Injuries in US High School Boys’ Soccer (2005–2006 Through 2013–2014) and National Collegiate Athletic Association Men’s Soccer (2004–2005 Through 2013–2014).” *Journal of Athletic Training* 53 (9): 893–905. https://doi.org/10.4085/1062-6050-166-17.
Koerte, Inga K., Vivian Schultz, Valerie J. Sydnor, David R. Howell, Jeffrey P. Guenette, Emily Dennis, Janna Kochsiek, et al. 2020. “Sex-Related Differences in the Effects of Sports-Related Concussion: A Review.” *Journal of Neuroimaging* 30 (4): 387–409. https://doi.org/10.1111/jon.12726.
Korhonen, Marko T., Antti Mero, and Harri Suominen. 2003. “Age-Related Differences in 100-m Sprint Performance in Male and Female Master Runners:” *Medicine & Science in Sports & Exercise* 35 (8): 1419–28. https://doi.org/10.1249/01.MSS.0000079080.15333.CA.
Koulouris, George, and David Connell. 2005. “Hamstring Muscle Complex: An Imaging Review.” *RadioGraphics* 25 (3): 571–86. https://doi.org/10.1148/rg.253045711.
Krug, Mickey I., Pamela M. Vacek, Rebecca Choquette, Bruce D. Beynnon, and James R. Slauterbeck. 2022. “Compliance and Fidelity With an Injury Prevention Exercise Program in High School Athletics.” *Sports Health: A Multidisciplinary Approach* 14 (4): 483–89. https://doi.org/10.1177/19417381211043120.
Kupperman, Natalie, and Jay Hertel. 2020. “Global Positioning System–Derived Workload Metrics and Injury Risk in Team-Based Field Sports: A Systematic

Review." *Journal of Athletic Training* 55 (9): 931–43. https://doi.org/10.4085/1062-6050-473-19.

Ladiesgaelic.ie. n.d. *The Athletic Development and Injury Prevention Program*. https://ladiesgaelic.ie/wp-content/uploads/2018/04/The-Athletic-Development-and-Injury-Prevention-Warm-Up-Program-1.pdf.

Lahti, Johan, Jurdan Mendiguchia, Juha Ahtiainen, Luis Anula, Tuomas Kononen, Mikko Kujala, Anton Matinlauri, et al. 2020. "Multifactorial Individualised Programme for Hamstring Muscle Injury Risk Reduction in Professional Football: Protocol for a Prospective Cohort Study." *BMJ Open Sport & Exercise Medicine* 6 (1): e000758. https://doi.org/10.1136/bmjsem-2020-000758.

Lane, Aoife. n.d. "Never Enough Time. The Experience of Third Level Student County GAA Players." Waterford Institute of Technology. https://www.gaelicplayers.com/wp-content/uploads/2019/04/GPA-Student-Report-April-2015.pdf.

LaPrade, Robert F., Patrick M. Morgan, Fred A. Wentorf, Steinar Johansen, and Lars Engebretsen. 2007. "The Anatomy of the Posterior Aspect of the Knee: An Anatomic Study." *The Journal of Bone & Joint Surgery* 89 (4): 758–64. https://doi.org/10.2106/JBJS.F.00120.

Larruskain, J., J. A. Lekue, N. Diaz, A. Odriozola, and S. M. Gil. 2018. "A Comparison of Injuries in Elite Male and Female Football Players: A Five-Season Prospective Study." *Scandinavian Journal of Medicine & Science in Sports* 28 (1): 237–45. https://doi.org/10.1111/sms.12860.

Lauersen, Jeppe Bo, Ditte Marie Bertelsen, and Lars Bo Andersen. 2014. "The Effectiveness of Exercise Interventions to Prevent Sports Injuries: A Systematic Review and Meta-Analysis of Randomised Controlled Trials." *British Journal of Sports Medicine* 48 (11): 871–77. https://doi.org/10.1136/bjsports-2013-092538.

Lee Dow, Connor, Ryan G. Timmins, Joshua D. Ruddy, Morgan D. Williams, Nirav Maniar, Jack T. Hickey, Matthew N. Bourne, and David A. Opar. 2021. "Prediction of Hamstring Injuries in Australian Football Using Biceps Femoris Architectural Risk Factors Derived From Soccer." *The American Journal of Sports Medicine* 49 (13): 3687–95. https://doi.org/10.1177/03635465211041686.

Lee, I-Min, Eric J Shiroma, Felipe Lobelo, Pekka Puska, Steven N Blair, and Peter T Katzmarzyk. 2012. "Effect of Physical Inactivity on Major Non-Communicable Diseases Worldwide: An Analysis of Burden of Disease and Life Expectancy." *The Lancet* 380 (9838): 219–29. https://doi.org/10.1016/S0140-6736(12)61031-9.

Lee, Marcus J. C., Siobhan L. Reid, Bruce C. Elliott, and David G. Lloyd. 2009. "Running Biomechanics and Lower Limb Strength Associated with Prior Hamstring Injury." *Medicine & Science in Sports & Exercise* 41 (10): 1942–51. https://doi.org/10.1249/MSS.0b013e3181a55200.

Li, Li, Dennis Landin, Janene Grodesky, and Joseph Myers. 2002. "The Function of Gastrocnemius as a Knee Flexor at Selected Knee and Ankle Angles." *Journal of Electromyography and Kinesiology* 12 (5): 385–90. https://doi.org/10.1016/S1050-6411(02)00049-4.

Li, Ryan T., Michael J. Salata, Sagar Rambhia, Joe Sheehan, and James E. Voos. 2020. "Does Overexertion Correlate With Increased Injury? The Relationship Between Player Workload and Soft Tissue Injury in Professional American Football Players Using Wearable Technology." *Sports Health: A Multidisciplinary Approach* 12 (1): 66–73. https://doi.org/10.1177/1941738119868477.

Lieber, R. L., and J. Fridén. 1988. "Selective Damage of Fast Glycolytic Muscle Fibres with Eccentric Contraction of the Rabbit Tibialis Anterior." *Acta Physiologica*

Scandinavica 133 (4): 587–88. https://doi.org/10.1111/j.1748-1716.1988.tb08446.x.
Lieber, R. L., and J. Friden. 1993. "Muscle Damage Is Not a Function of Muscle Force but Active Muscle Strain." *Journal of Applied Physiology* 74 (2): 520–26. https://doi.org/10.1152/jappl.1993.74.2.520.
Lieber, Richard L., and Samuel R. Ward. 2011. "Skeletal Muscle Design to Meet Functional Demands." *Philosophical Transactions of the Royal Society B: Biological Sciences* 366 (1570): 1466–76. https://doi.org/10.1098/rstb.2010.0316.
Lima-E-Silva, Felipe Xavier de, Gabriel Santos Oliveira, Thales Menezes Medeiros, Maurício Pinto Dornelles, João Breno Araujo Ribeiro-Alvares, and Bruno Manfredini Baroni. 2020. "Flexibility, Strength, and Fascicle Length of Football Players with and without History of Hamstring Strain Injury in the Prior Season." *Science and Medicine in Football* 4 (4): 322–28. https://doi.org/10.1080/24733938.2020.1751871.
Lincoln, Andrew E., Richard Y. Hinton, Jon L. Almquist, Sean L. Lager, and Randall W. Dick. 2007. "Head, Face, and Eye Injuries in Scholastic and Collegiate Lacrosse: A 4-Year Prospective Study." *The American Journal of Sports Medicine* 35 (2): 207–15. https://doi.org/10.1177/0363546506293900.
Lindblom, Hanna, Markus Waldén, Siw Carlfjord, and Martin Hägglund. 2014. "Implementation of a Neuromuscular Training Programme in Female Adolescent Football: 3-Year Follow-up Study after a Randomised Controlled Trial." *British Journal of Sports Medicine* 48 (19): 1425–30. https://doi.org/10.1136/bjsports-2013-093298.
Lodge, Clare, Diarmuid Tobin, Brian O'Rourke, and Kristian Thorborg. 2020. "Reliability and Validity of a New Eccentric Hamstring Strength Measurement Device." *Archives of Rehabilitation Research and Clinical Translation* 2 (1): 100034. https://doi.org/10.1016/j.arrct.2019.100034.
Lolli, Lorenzo, Roald Bahr, Matthew Weston, Rodney Whiteley, Montassar Tabben, Daniele Bonanno, Warren Gregson, Karim Chamari, Valter Di Salvo, and Nicol van Dyk. 2020. "No Association between Perceived Exertion and Session Duration with Hamstring Injury Occurrence in Professional Football." *Scandinavian Journal of Medicine & Science in Sports* 30 (3): 523–30. https://doi.org/10.1111/sms.13591.
López-Valenciano, Alejandro, Iñaki Ruiz-Pérez, Alberto Garcia-Gómez, Francisco J Vera-Garcia, Mark De Ste Croix, Gregory D Myer, and Francisco Ayala. 2020. "Epidemiology of Injuries in Professional Football: A Systematic Review and Meta-Analysis." *British Journal of Sports Medicine* 54 (12): 711–18. https://doi.org/10.1136/bjsports-2018-099577.
Lowther, D, A O'Connor, Am Clifford, and K O'Sullivan. 2012. "The Relationship between Lower Limb Flexibility and Hamstring Injury in Male Gaelic Footballers." *Physiotherapy Practice and Research* 33 (1): 22–28. https://doi.org/10.3233/PPR-2012-33105.
Lunn, Pete, Elish Kelly, and Nick Fitzpatrick. 2013. "Keeping Them in the Game: Taking Up and Dropping Out of Sport and Exercise in Ireland." ESRI.
Lynch, Patricia, and Robert Carroll. 2017. "To Compare the Type of Passing in Gaelic Football at Senior Inter-County Level Historically to Modern Day." *International Journal of Performance Analysis in Sport* 17 (6): 986–95. https://doi.org/10.1080/24748668.2017.1416526.
Made, A. D. van der, T. Wieldraaijer, G. M. Kerkhoffs, R. P. Kleipool, L. Engebretsen, C. N. van Dijk, and P. Golanó. 2015. "The Hamstring Muscle Complex." *Knee*

Surgery, Sports Traumatology, Arthroscopy 23 (7): 2115–22. https://doi.org/10.1007/s00167-013-2744-0.

Mair, Scott D., Anthony V. Seaber, Richard R. Glisson, and William E. Garrett. 1996. “The Role of Fatigue in Susceptibility to Acute Muscle Strain Injury.” *The American Journal of Sports Medicine* 24 (2): 137–43. https://doi.org/10.1177/036354659602400203.

Malone, Shane, Kieran D. Collins, A.P Mcrobert, J Morton, and Dominic A. Doran. 2014. “Accuracy and Reliability of VXsport Global Positioning System in Intermittent Activity.” *Amsterdam: Proceedings of the 19th Annual Congress of the European College of Sport Science.*

Malone, Shane, Kieran Collins, Allistair McRobert, and Dominic Doran. 2021. “Quantifying the Training and Match-Play External and Internal Load of Elite Gaelic Football Players.” *Applied Sciences* 11 (4): 1756. https://doi.org/10.3390/app11041756.

Malone, Shane, Brian Hughes, and Kieran Collins. 2019. “Effect of Training Load Distribution on Aerobic Fitness Measures in Hurling Players.” *Journal of Strength and Conditioning Research* 33 (3): 825–30. https://doi.org/10.1519/JSC.0000000000002004.

Malone, Shane, Brian Hughes, Kieran Collins, and Ibrahim Akubat. 2020. “Methods of Monitoring Training Load and Their Association With Changes Across Fitness Measures in Hurling Players.” *Journal of Strength and Conditioning Research* 34 (1): 225–34. https://doi.org/10.1519/JSC.0000000000002655.

Malone, Shane, Aideen McGuinness, John David Duggan, Amy Murphy, Kieran Collins, and Cliodhna O’Connor. 2022. “The Running Performance of Elite Ladies Gaelic Football with Respect to Position and Halves of Play.” *Sport Sciences for Health*, August. https://doi.org/10.1007/s11332-022-00991-4.

Malone, Shane, Adam Owen, Matt Newton, Bruno Mendes, Kieran D. Collins, and Tim J. Gabbett. 2017. “The Acute:Chonic Workload Ratio in Relation to Injury Risk in Professional Soccer.” *Journal of Science and Medicine in Sport* 20 (6): 561–65. https://doi.org/10.1016/j.jsams.2016.10.014.

Malone, Shane, Mark Roe, Dominic A. Doran, Tim J. Gabbett, and Kieran Collins. 2017a. “High Chronic Training Loads and Exposure to Bouts of Maximal Velocity Running Reduce Injury Risk in Elite Gaelic Football.” *Journal of Science and Medicine in Sport* 20 (3): 250–54. https://doi.org/10.1016/j.jsams.2016.08.005.

Malone, Shane, Mark Roe, Dominic A. Doran, Tim J. Gabbett, and Kieran D. Collins. 2017b. “Protection Against Spikes in Workload With Aerobic Fitness and Playing Experience: The Role of the Acute:Chronic Workload Ratio on Injury Risk in Elite Gaelic Football.” *International Journal of Sports Physiology and Performance* 12 (3): 393–401. https://doi.org/10.1123/ijspp.2016-0090.

Malone, Shane, Barry Solan, and Kieran Collins. 2017. “The Running Performance Profile of Elite Gaelic Football Match-Play.” *Journal of Strength and Conditioning Research* 31 (1): 30–36. https://doi.org/10.1519/JSC.0000000000001477.

Malone, Shane, Barry Solan, Kieran D. Collins, and Dominic A. Doran. 2016. “Positional Match Running Performance in Elite Gaelic Football.” *Journal of Strength and Conditioning Research* 30 (8): 2292–98. https://doi.org/10.1519/JSC.0000000000001309.

Malone, Shane, Barry Solan, Kieran Collins, and Dominic Doran. 2017. “The Metabolic Power and Energetic Demands of Elite Gaelic Football Match Play.” *The Journal*

of Sports Medicine and Physical Fitness 57 (5). https://doi.org/10.23736/S0022-4707.16.06233-2.
Mangan, Shane, Kieran Collins, Con Burns, and Cian O'Neill. 2020. "The Positional Technical and Running Performance of Sub-Elite Gaelic Football." *Science and Medicine in Football* 4 (3): 182–91. https://doi.org/10.1080/24733938.2019.1679872.
———. 2022. "A Tactical Periodisation Model for Gaelic Football." *International Journal of Sports Science & Coaching* 17 (1): 208–19. https://doi.org/10.1177/17479541211016269.
Mangan, Shane, Martin Ryan, Simon Devenney, Aidan Shovlin, Jason McGahan, Shane Malone, Cian O'Neill, Con Burns, and Kieran Collins. 2017. "The Relationship between Technical Performance Indicators and Running Performance in Elite Gaelic Football." *International Journal of Performance Analysis in Sport* 17 (5): 706–20. https://doi.org/10.1080/24748668.2017.1387409.
Marr, Daniel, Simon Coleman, and Carla Mccabe. 2014. "The Epidemiology of UK University Football Injuries within the 2011-2012 Season." *International Journal of Sports Science* 4 (6A): 49–55.
Martinez, Jessica C., Stephanie M. Mazerolle, Craig R. Denegar, Michael F. Joseph, Kelly D. Pagnotta, Thomas H. Trojian, and Lindsay J. DiStefano. 2017. "Female Adolescent Athletes' Attitudes and Perspectives on Injury Prevention Programs." *Journal of Science and Medicine in Sport* 20 (2): 146–51. https://doi.org/10.1016/j.jsams.2016.06.009.
Martins de Oliveira, Gabriela, Giovana Araujo Kretli Mota, Caio Sain Vallio, Alexandre Dias Lopes, and Luiz Hespanhol. 2022. "What Are the Facilitators and Barriers to Develop a Running-Related Injury Prevention Program? A Qualitative Study." *Physiotherapy Theory and Practice* 38 (13): 2798–2805. https://doi.org/10.1080/09593985.2021.1967538.
Matinlauri, Anton, Pedro E. Alcaraz, Tomás T. Freitas, Jurdan Mendiguchia, Afshin Abedin-Maghanaki, Alberto Castillo, Enrique Martínez-Ruiz, Jorge Carlos-Vivas, and Daniel D. Cohen. 2019. "A Comparison of the Isometric Force Fatigue-Recovery Profile in Two Posterior Chain Lower Limb Tests Following Simulated Soccer Competition." Edited by Dragan Mirkov. *PLOS ONE* 14 (5): e0206561. https://doi.org/10.1371/journal.pone.0206561.
Matz, Samuel O., and Gregg Nibbelink. 2004. "Injuries in Intercollegiate Women's Lacrosse." *The American Journal of Sports Medicine* 32 (3): 608–11. https://doi.org/10.1177/0363546503262172.
Mawson, Robin, Michael J Creech, Devin C Peterson, Forough Farrokhyar, and Olufemi R Ayeni. 2018. "Lower Limb Injury Prevention Programs in Youth Soccer: A Survey of Coach Knowledge, Usage, and Barriers." *Journal of Experimental Orthopaedics* 5 (1): 43. https://doi.org/10.1186/s40634-018-0160-6.
McCall, Alan, Gregory Dupont, and Jan Ekstrand. 2016. "Injury Prevention Strategies, Coach Compliance and Player Adherence of 33 of the UEFA Elite Club Injury Study Teams: A Survey of Teams' Head Medical Officers." *British Journal of Sports Medicine* 50 (12): 725–30. https://doi.org/10.1136/bjsports-2015-095259.
———. 2018. "Internal Workload and Non-Contact Injury: A One-Season Study of Five Teams from the UEFA Elite Club Injury Study." *British Journal of Sports Medicine* 52 (23): 1517–22. https://doi.org/10.1136/bjsports-2017-098473.
McCrory, Paul, Willem Meeuwisse, Jiří Dvorak, Mark Aubry, Julian Bailes, Steven Broglio, Robert C Cantu, et al. 2017. "Consensus Statement on Concussion in Sport—the 5 th International Conference on Concussion in Sport Held in Berlin,

October 2016.” *British Journal of Sports Medicine*, April, bjsports-2017-097699. https://doi.org/10.1136/bjsports-2017-097699.
McGahan, Jason, Con Burns, Seán Lacey, Tim Gabbett, and Cian O’Neil. 2020. “Investigation in to the Positional Running Demands of Elite Gaelic Football Players: How Competition Data Can Inform Training Practice.” *Journal of Strength and Conditioning Research* 34 (7): 2040–47. https://doi.org/10.1519/JSC.0000000000002492.
McGahan, Jason H., Shane Mangan, Kieran Collins, Con Burns, Tim Gabbett, and Cian O’Neill. 2021. “Match-Play Running Demands and Technical Performance Among Elite Gaelic Footballers: Does Divisional Status Count?” *Journal of Strength and Conditioning Research* 35 (1): 169–75. https://doi.org/10.1519/JSC.0000000000002450.
McGlashan, Angela, Glenda Verrinder, and Evert Verhagen. 2018. “Working towards More Effective Implementation, Dissemination and Scale-Up of Lower-Limb Injury-Prevention Programs: Insights from Community Australian Football Coaches.” *International Journal of Environmental Research and Public Health* 15 (2): E351. https://doi.org/10.3390/ijerph15020351.
McGrath, Timothy M., Billy T. Hulin, Nathan Pickworth, Alex Clarke, and Ryan G. Timmins. 2020. “Determinants of Hamstring Fascicle Length in Professional Rugby League Athletes.” *Journal of Science and Medicine in Sport* 23 (5): 524–28. https://doi.org/10.1016/j.jsams.2019.12.006.
McIntosh, A S. 2005. “Risk Compensation, Motivation, Injuries, and Biomechanics in Competitive Sport.” *British Journal of Sports Medicine* 39 (1): 2–3. https://doi.org/10.1136/bjsm.2004.016188.
McIntyre, M C. 2005. “A Comparison of the Physiological Profiles of Elite Gaelic Footballers, Hurlers, and Soccer Players.” *British Journal of Sports Medicine* 39 (7): 437–39. https://doi.org/10.1136/bjsm.2004.013631.
McKay, Carly D, Kathrin Steffen, Maria Romiti, Caroline F Finch, and Carolyn A Emery. 2014. “The Effect of Coach and Player Injury Knowledge, Attitudes and Beliefs on Adherence to the FIFA 11+ Programme in Female Youth Soccer.” *British Journal of Sports Medicine* 48 (17): 1281–86. https://doi.org/10.1136/bjsports-2014-093543.
McMahon, Kathryn A, Terry Nolan, Catherine M Bennett, and John B Carlin. 1993. “Australian Rules Football Injuries in Children and Adolescents.” *Medical Journal of Australia* 159 (5): 301–6. https://doi.org/10.5694/j.1326-5377.1993.tb137864.x.
Mechelen, Willem van, Hynek Hlobil, and Han C.G. Kemper. 1992. “Incidence, Severity, Aetiology and Prevention of Sports Injuries: A Review of Concepts.” *Sports Medicine* 14 (2): 82–99. https://doi.org/10.2165/00007256-199214020-00002.
Medeiros, Diulian Muniz, César Marchiori, and Bruno Manfredini Baroni. 2021. “Effect of Nordic Hamstring Exercise Training on Knee Flexors Eccentric Strength and Fascicle Length: A Systematic Review and Meta-Analysis.” *Journal of Sport Rehabilitation* 30 (3): 482–91. https://doi.org/10.1123/jsr.2019-0388.
Meeuwisse, Willem H. 1994. “Assessing Causation in Sport Injury: A Multifactorial Model.” *Clinical Journal of Sport Medicine* 4 (3): 166–70.
Meeuwisse, Willem H, Hugh Tyreman, Brent Hagel, and Carolyn Emery. 2007. “A Dynamic Model of Etiology in Sport Injury: The Recursive Nature of Risk and Causation:” *Clinical Journal of Sport Medicine* 17 (3): 215–19. https://doi.org/10.1097/JSM.0b013e3180592a48.

Melzer, Katarina, Bengt Kayser, and Claude Pichard. 2004. "Physical Activity: The Health Benefits Outweigh the Risks:" *Current Opinion in Clinical Nutrition and Metabolic Care* 7 (6): 641–47. https://doi.org/10.1097/00075197-200411000-00009.

Mendiguchia, Jurdan, Eduard Alentorn-Geli, Fernando Idoate, and Gregory D Myer. 2013. "Rectus Femoris Muscle Injuries in Football: A Clinically Relevant Review of Mechanisms of Injury, Risk Factors and Preventive Strategies." *British Journal of Sports Medicine* 47 (6): 359–66. https://doi.org/10.1136/bjsports-2012-091250.

Mendiguchia, Jurdan, Filipe Conceição, Pascal Edouard, Marco Fonseca, Rogerio Pereira, Hernani Lopes, Jean-Benoît Morin, and Pedro Jiménez-Reyes. 2020. "Sprint versus Isolated Eccentric Training: Comparative Effects on Hamstring Architecture and Performance in Soccer Players." Edited by Daniel Boullosa. *PLOS ONE* 15 (2): e0228283. https://doi.org/10.1371/journal.pone.0228283.

Mendonça, Luciana D, Joke Schuermans, Evi Wezenbeek, and Erik Witvrouw. 2021. "Worldwide Sports Injury Prevention." *International Journal of Sports Physical Therapy* 16 (1): 285–87. https://doi.org/10.26603/001c.18700.

Messer, Daniel J., Anthony J. Shield, Morgan D. Williams, Ryan G. Timmins, and Matthew N. Bourne. 2020. "Hamstring Muscle Activation and Morphology Are Significantly Altered 1–6 Years after Anterior Cruciate Ligament Reconstruction with Semitendinosus Graft." *Knee Surgery, Sports Traumatology, Arthroscopy* 28 (3): 733–41. https://doi.org/10.1007/s00167-019-05374-w.

Møller, Merete, Mette K. Zebis, Grethe Myklebust, Martin Lind, Niels Wedderkopp, and Sheree Bekker. 2021. "'Is It Fun and Does It Enhance My Performance?' – Key Implementation Considerations for Injury Prevention Programs in Youth Handball." *Journal of Science and Medicine in Sport* 24 (11): 1136–42. https://doi.org/10.1016/j.jsams.2021.04.017.

Mooney, Tommy, Shane Malone, Erwan Izri, Sami Dowling, and Ian A. J. Darragh. 2021. "The Running Performance of Elite U20 Gaelic Football Match-Play." *Sport Sciences for Health* 17 (3): 771–79. https://doi.org/10.1007/s11332-021-00760-9.

Moreno-Perez, Víctor, Miguel Angel Campos-Vazquez, Javier Toscano, Victor Javier Sotos-Martinez, Roberto López-Del Campo, Ricardo Resta, and Juan Del Coso. 2022. "Influence of the Weekly and Match-Play Load on Muscle Injury in Professional Football Players." *International Journal of Sports Medicine* 43 (09): 783–90. https://doi.org/10.1055/a-1533-2110.

Moreno-Pérez, Víctor, Juan Del Coso, Roberto López-Del Campo, Ricardo Resta, José Romero-Sangüesa, Javier Courel-Ibáñez, and Alberto Méndez-Villanueva. 2023. "Reduced Match Exposure in the Previous 2 Matches Accounts for Hamstring Muscle Injury Incidence in Professional Football Players." *Sports Health: A Multidisciplinary Approach*, March, 194173812311581. https://doi.org/10.1177/19417381231158117.

Morgan, Elle A, Samuel T Johnson, Viktor E Bovbjerg, and Marc F Norcross. 2018. "Associations between Player Age and Club Soccer Coaches' Perceptions of Injury Risk and Lower Extremity Injury Prevention Program Use." *International Journal of Sports Science & Coaching* 13 (1): 122–28. https://doi.org/10.1177/1747954117707480.

Morin, Jean-Benoît, Philippe Gimenez, Pascal Edouard, Pierrick Arnal, Pedro Jiménez-Reyes, Pierre Samozino, Matt Brughelli, and Jurdan Mendiguchia. 2015. "Sprint Acceleration Mechanics: The Major Role of Hamstrings in Horizontal Force

Production." *Frontiers in Physiology* 6 (December). https://doi.org/10.3389/fphys.2015.00404.
Motte, Sarah J. de la, Peter Lisman, Timothy C. Gribbin, Kaitlin Murphy, and Patricia A. Deuster. 2019. "Systematic Review of the Association Between Physical Fitness and Musculoskeletal Injury Risk: Part 3—Flexibility, Power, Speed, Balance, and Agility." *Journal of Strength and Conditioning Research* 33 (6): 1723–35. https://doi.org/10.1519/JSC.0000000000002382.
Mufty, S., P. Bollars, L. Vanlommel, K. Van Crombrugge, K. Corten, and J. Bellemans. 2015. "Injuries in Male versus Female Soccer Players: Epidemiology of a Nationwide Study." *Acta Orthopaedica Belgica* 81 (2): 289–95.
Murphy, John C, Conor Gissane, and Catherine Blake. 2010. "Injury in Elite County-Level Hurling: A Prospective Study." *British Journal of Sports Medicine* 46 (2): 138–42. https://doi.org/10.1136/bjsm.2010.072132.
Murphy, John C, Edwenia O'Malley, Conor Gissane, and Catherine Blake. 2012. "Incidence of Injury in Gaelic Football." *The American Journal of Sports Medicine* 40 (9): 2113–20.
Myers, Natalie L., Guadalupe Mexicano, and Kristin V. Aguilar. 2020. "The Association Between Noncontact Injuries and the Acute—Chronic Workload Ratio in Elite-Level Athletes: A Critically Appraised Topic." *Journal of Sport Rehabilitation* 29 (1): 127–30. https://doi.org/10.1123/jsr.2018-0207.
Navandar, Archit, Santiago Veiga, Gonzalo Torres, David Chorro, and Enrique Navarro. 2018. "A Previous Hamstring Injury Affects Kicking Mechanics in Soccer Players." *The Journal of Sports Medicine and Physical Fitness* 58 (12). https://doi.org/10.23736/S0022-4707.18.07852-0.
Newell, M, S Grant, A Henry, and J Newell. 2006. "Incidence of Injury in Elite Gaelic Footballers" 99 (9): 3.
Nielsen, Rasmus Oestergaard, Ian Shrier, Marti Casals, Albertro Nettel-Aguirre, Merete Møller, Caroline Bolling, Natália Franco Netto Bittencourt, et al. 2020. "Statement on Methods in Sport Injury Research from the 1st METHODS MATTER Meeting, Copenhagen, 2019." *British Journal of Sports Medicine* 54 (15): 941–941. https://doi.org/10.1136/bjsports-2019-101323.
Nishida, Satoru, Wataru Ito, Taisuke Ohishi, Riku Yoshida, Shigeru Sato, and Masatoshi Nakamura. 2021. "The Effect of Ankle Position on Peak Eccentric Force during The Nordic Hamstring Exercise." *Journal of Sports Science and Medicine*, November, 43–48. https://doi.org/10.52082/jssm.2022.43.
Norcross, Marc F., Samuel T. Johnson, Viktor E. Bovbjerg, Michael C. Koester, and Mark A. Hoffman. 2016. "Factors Influencing High School Coaches' Adoption of Injury Prevention Programs." *Journal of Science and Medicine in Sport* 19 (4): 299–304. https://doi.org/10.1016/j.jsams.2015.03.009.
O' Connor, Siobhán, Noel McCaffrey, Enda F. Whyte, and Kieran A. Moran. 2016. "Epidemiology of Injury in Male Adolescent Gaelic Games." *Journal of Science and Medicine in Sport* 19 (5): 384–88. https://doi.org/10.1016/j.jsams.2015.06.002.
O'Brien, J., W. Young, and C. F. Finch. 2017. "The Use and Modification of Injury Prevention Exercises by Professional Youth Soccer Teams." *Scandinavian Journal of Medicine & Science in Sports* 27 (11): 1337–46. https://doi.org/10.1111/sms.12756.
O'Brien, James, Alex Donaldson, and Caroline F Finch. 2016. "It Will Take More than an Existing Exercise Programme to Prevent Injury." *British Journal of Sports Medicine* 50 (5): 264–65. https://doi.org/10.1136/bjsports-2015-094841.

O'Brien, James, and Caroline F. Finch. 2014. "The Implementation of Musculoskeletal Injury-Prevention Exercise Programmes in Team Ball Sports: A Systematic Review Employing the RE-AIM Framework." *Sports Medicine* 44 (9): 1305–18. https://doi.org/10.1007/s40279-014-0208-4.

O'Brien, James, and Caroline F Finch. 2016. "Injury Prevention Exercise Programmes in Professional Youth Soccer: Understanding the Perceptions of Programme Deliverers." *BMJ Open Sport & Exercise Medicine* 2 (1): e000075. https://doi.org/10.1136/bmjsem-2015-000075.

O'Brien, James, and Caroline F. Finch. 2017. "Injury Prevention Exercise Programs for Professional Soccer: Understanding the Perceptions of the End-Users." *Clinical Journal of Sport Medicine* 27 (1): 1–9. https://doi.org/10.1097/JSM.0000000000000291.

O'Connor, Donna M. 2004. "Groin Injuries in Professional Rugby League Players: A Prospective Study." *Journal of Sports Sciences* 22 (7): 629–36. https://doi.org/10.1080/02640410310001655804.

O'Connor, S., N. McCaffrey, E. F. Whyte, and K. A. Moran. 2016. "Epidemiology of Injury in Male Collegiate Gaelic Footballers in One Season." *Scandinavian Journal of Medicine & Science in Sports* 27 (10): 1136–42. https://doi.org/10.1111/sms.12733.

O'Connor, Siobhán, Conor Bruce, Calvin Teahan, Elaine McDermott, and Enda Whyte. 2021. "Injuries in Collegiate Ladies Gaelic Footballers: A 2-Season Prospective Cohort Study." *Journal of Sport Rehabilitation* 30 (2): 261–66. https://doi.org/10.1123/jsr.2019-0468.

O'Connor, Siobhán, Conor Bruce, and Enda Whyte. 2022. "Does a Ten-Week Activate GAA Warm-up Intervention Improve Outcomes in Adult Male Hurlers?" *Physiotherapy Practice and Research* 43 (2): 189–97. https://doi.org/10.3233/PPR-220656.

O'Connor, Siobhán, and Peter Lacey. 2020. "Can We Improve Coaches' Injury Prevention Views and Implementation Practices in the Community Female Gaelic Sport of Camogie?" *BMJ Open Sport & Exercise Medicine* 6 (1): e000732. https://doi.org/10.1136/bmjsem-2019-000732.

O'Connor, Siobhán, Róisín Leahy, Enda Whyte, Paul O'Donovan, and Lauren Fortington. 2019. "Understanding Injuries in the Gaelic Sport of Camogie: The First National Survey of Self-Reported Worst Injuries." *International Journal of Athletic Therapy and Training* 24 (6): 243–48. https://doi.org/10.1123/ijatt.2018-0059.

O'Connor, Siobhán, Noel McCaffrey, Enda F. Whyte, Michael Fop, Brendan Murphy, and Kieran A. Moran. 2019. "Is Poor Hamstring Flexibility a Risk Factor for Hamstring Injury in Gaelic Games?" *Journal of Sport Rehabilitation* 28 (7): 677–81. https://doi.org/10.1123/jsr.2017-0304.

O'Connor, Siobhán, Kieran Moran, Aishling Sheridan, Shaunagh Brady, Conor Bruce, Erica Beidler, Anna Donnla O'Hagan, and Enda F. Whyte. 2021. "Fear Avoidance After Injury and Readiness to Return to Sport in Collegiate Male and Female Gaelic Games Players." *Sports Health* 13 (6): 532–39. https://doi.org/10.1177/1941738121999047.

O'Connor, Siobhán, Wesley O'Brien, and Peter Lacey. 2021. "The Implementation of a National Strategy to Encourage Injury Prevention Program Uptake in a Community Female Sport in Ireland: A Camogie Case Study." *International Sport Coaching Journal*, 1–8. https://doi.org/10.1123/iscj.2021-0020.

O'Connor, Siobhán, Enda Whyte, Lauren Fortington, and John Corrigan. 2022. "The Cost of Injury in Ladies Gaelic Football: A Nine-Year Analysis (2012–2020) of the LGFA's Injury Fund." *Journal of Science and Medicine in Sport*, October, S1440244022004418. https://doi.org/10.1016/j.jsams.2022.10.007.

O'Connor, Siobhán, Enda Whyte, Sean O'Hanlon, and Lauren Fortington. 2020. "Coach and Player Views Toward Injury Prevention Exercise Programs in Camogie: A Cross-Sectional Survey." *Athletic Training & Sports Health Care*, August. https://doi.org/10.3928/19425864-20200426-01.

O'Grady, Maggie, Damien Young, Kieran Collins, John Keane, Shane Malone, and Giuseppe Coratella. 2022. "An Investigation of the Sprint Performance of Senior Elite Camogie Players during Competitive Play." *Sport Sciences for Health* 18 (3): 905–13. https://doi.org/10.1007/s11332-021-00874-0.

O'Keeffe, Sinéad, Siobhán O'Connor, and Ní Chéilleachair. 2020. "Are Internal Load Measures Associated with Injuries in Male Adolescent Gaelic Football Players?" *European Journal of Sport Science* 20 (2): 249–60.

O'Malley, E, J Murphy, C Gissane, and C Blake. 2014. "EPIDEMIOLOGY OF LOWER LIMB INJURY IN GAELIC FOOTBALL AND HURLING." *British Journal of Sports Medicine* 48 (7): 646.3-647. https://doi.org/10.1136/bjsports-2014-093494.230.

O'Malley, Edwenia, John C. Murphy, Ulrik McCarthy Persson, Conor Gissane, and Catherine Blake. 2017. "The Effects of the Gaelic Athletic Association 15 Training Program on Neuromuscular Outcomes in Gaelic Football and Hurling Players: A Randomized Cluster Trial." *Journal of Strength and Conditioning Research* 31 (8): 2119–30. https://doi.org/10.1519/JSC.0000000000001564.

Opar, David A., Timothy Piatkowski, Morgan D. Williams, and Anthony J. Shield. 2013. "A Novel Device Using the Nordic Hamstring Exercise to Assess Eccentric Knee Flexor Strength: A Reliability and Retrospective Injury Study." *Journal of Orthopaedic & Sports Physical Therapy* 43 (9): 636–40. https://doi.org/10.2519/jospt.2013.4837.

Opar, David A., Joshua D. Ruddy, Morgan D. Williams, Nirav Maniar, Jack T. Hickey, Matthew N. Bourne, Tania Pizzari, and Ryan G. Timmins. 2022. "Screening Hamstring Injury Risk Factors Multiple Times in a Season Does Not Improve the Identification of Future Injury Risk." *Medicine & Science in Sports & Exercise* 54 (2): 321–29. https://doi.org/10.1249/MSS.0000000000002782.

Opar, David A., Ryan G. Timmins, Fearghal P. Behan, Jack T. Hickey, Nicol van Dyk, Kara Price, and Nirav Maniar. 2021. "Is Pre-Season Eccentric Strength Testing During the Nordic Hamstring Exercise Associated with Future Hamstring Strain Injury? A Systematic Review and Meta-Analysis." *Sports Medicine* 51 (9): 1935–45. https://doi.org/10.1007/s40279-021-01474-1.

Opar, David A., Morgan D. Williams, and Anthony J. Shield. 2012. "Hamstring Strain Injuries: Factors That Lead to Injury and Re-Injury." *Sports Medicine* 42 (3): 209–26. https://doi.org/10.2165/11594800-000000000-00000.

Opar, David A., Morgan D. Williams, Ryan G. Timmins, Nuala M. Dear, and Anthony J. Shield. 2013. "Knee Flexor Strength and Bicep Femoris Electromyographical Activity Is Lower in Previously Strained Hamstrings." *Journal of Electromyography and Kinesiology* 23 (3): 696–703. https://doi.org/10.1016/j.jelekin.2012.11.004.

Opar, David A., Morgan D. Williams, Ryan G. Timmins, Jack Hickey, Steven J. Duhig, and Anthony J. Shield. 2015. "Eccentric Hamstring Strength and Hamstring Injury

Risk in Australian Footballers." *Medicine & Science in Sports & Exercise* 47 (4): 857–65. https://doi.org/10.1249/MSS.0000000000000465.

Orchard, John, and Thomas M. Best. 2002. "The Management of Muscle Strain Injuries: An Early Return Versus the Risk of Recurrence:" *Clinical Journal of Sport Medicine* 12 (1): 3–5. https://doi.org/10.1097/00042752-200201000-00004.

Orchard, John W. 2001. "Intrinsic and Extrinsic Risk Factors for Muscle Strains in Australian Football." *The American Journal of Sports Medicine* 29 (3): 300–303. https://doi.org/10.1177/03635465010290030801.

Orchard, John W., Tim Driscoll, Hugh Seward, and Jessica J. Orchard. 2012. "Relationship between Interchange Usage and Risk of Hamstring Injuries in the Australian Football League." *Journal of Science and Medicine in Sport* 15 (3): 201–6. https://doi.org/10.1016/j.jsams.2011.11.250.

Orchard, John William. 2015. "Men at Higher Risk of Groin Injuries in Elite Team Sports: A Systematic Review." *British Journal of Sports Medicine* 49 (12): 798–802. https://doi.org/10.1136/bjsports-2014-094272.

Owoeye, Oluwatoyosi B A, Carly D McKay, Evert A L M Verhagen, and Carolyn A Emery. 2018. "Advancing Adherence Research in Sport Injury Prevention." *British Journal of Sports Medicine* 52 (17): 1078–79. https://doi.org/10.1136/bjsports-2017-098272.

Parsons, Joanne L, Stephanie E Coen, and Sheree Bekker. 2021. "Anterior Cruciate Ligament Injury: Towards a Gendered Environmental Approach." *British Journal of Sports Medicine* 55 (17): 984–90. https://doi.org/10.1136/bjsports-2020-103173.

Peck, Karen Y., Dana A. Johnston, Brett D. Owens, and Kenneth L. Cameron. 2013. "The Incidence of Injury Among Male and Female Intercollegiate Rugby Players." *Sports Health: A Multidisciplinary Approach* 5 (4): 327–33. https://doi.org/10.1177/1941738113487165.

Perera, Nirmala K.P., and Martin Hägglund. 2020. "We Have the Injury Prevention Exercise Programme, but How Well Do Youth Follow It?" *Journal of Science and Medicine in Sport* 23 (5): 463–68. https://doi.org/10.1016/j.jsams.2019.11.008.

Pfirrmann, Daniel, Mark Herbst, Patrick Ingelfinger, Perikles Simon, and Suzan Tug. 2016. "Analysis of Injury Incidences in Male Professional Adult and Elite Youth Soccer Players: A Systematic Review." *Journal of Athletic Training* 51 (5): 410–24. https://doi.org/10.4085/1062-6050-51.6.03.

Philippon, Marc J., Fernando P. Ferro, Kevin J. Campbell, Max P. Michalski, Mary T. Goldsmith, Brian M. Devitt, Coen A. Wijdicks, and Robert F. LaPrade. 2015. "A Qualitative and Quantitative Analysis of the Attachment Sites of the Proximal Hamstrings." *Knee Surgery, Sports Traumatology, Arthroscopy* 23 (9): 2554–61. https://doi.org/10.1007/s00167-014-3074-6.

Putukian, M, M Aubry, and P McCrory. 2009. "Return to Play after Sports Concussion in Elite and Non-Elite Athletes?" *British Journal of Sports Medicine* 43 (Suppl_1): i28–31. https://doi.org/10.1136/bjsm.2009.058230.

Räisänen, Anu M., Oluwatoyosi B. A. Owoeye, Kimberley Befus, Carla van den Berg, Kati Pasanen, and Carolyn A. Emery. 2021. "Warm-Ups and Coaches' Perceptions: Searching for Clues to Improve Injury Prevention in Youth Basketball." *Frontiers in Sports and Active Living* 3 (February): 619291. https://doi.org/10.3389/fspor.2021.619291.

Rees, Huw, James Matthews, Ulrik McCarthy Persson, Eamonn Delahunt, Colin Boreham, and Catherine Blake. 2021. "Coaches' Attitudes to Injury and Injury Prevention: A Qualitative Study of Irish Field Hockey Coaches." *BMJ Open Sport*

& Exercise Medicine 7 (3): e001074. https://doi.org/10.1136/bmjsem-2021-001074.

Reilly, John, and Courtney Kipps. 2017. “The Implementation and Adoption of the Injury Prevention Exercise Programeme GAA 15 in Gaelic Football Club Teams in the Counties of Mayo and London.” *British Journal of Sports Medicine* 51 (4): 377.2-377. https://doi.org/10.1136/bjsports-2016-097372.237.

Reilly, T., and D. Doran. 2001. “Science and Gaelic Football: A Review.” *Journal of Sports Sciences* 19 (3): 181–93. https://doi.org/10.1080/026404101750095330.

Reilly, Thomas, and Kieran Collins. 2008. “Science and the Gaelic Sports: Gaelic Football and Hurling.” *European Journal of Sport Science* 8 (5): 231–40. https://doi.org/10.1080/17461390802251851.

Rimmer, Esther E, Jasper Verheul, and Mark Lake. 2020. “Effects of Fatigue from Repeated Sprints on Hamstring Muscle Activation Patterns During Running.” *ISBS Proceedings Archieve* 38 (1).

Roberts, Simon P., Grant Trewartha, Rob J. Higgitt, Joe El-Abd, and Keith A. Stokes. 2008. “The Physical Demands of Elite English Rugby Union.” *Journal of Sports Sciences* 26 (8): 825–33. https://doi.org/10.1080/02640410801942122.

Robles-Palazón, Francisco Javier, Alejandro López-Valenciano, Mark De Ste Croix, Jon L. Oliver, Alberto García-Gómez, Pilar Sainz De Baranda, and Francisco Ayala. 2022. “Epidemiology of Injuries in Male and Female Youth Football Players: A Systematic Review and Meta-Analysis.” *Journal of Sport and Health Science* 11 (6): 681–95. https://doi.org/10.1016/j.jshs.2021.10.002.

Rodgers, Cooper D., and Avais Raja. 2023. “Anatomy, Bony Pelvis and Lower Limb, Hamstring Muscle.” In *StatPearls*. Treasure Island (FL): StatPearls Publishing. http://www.ncbi.nlm.nih.gov/books/NBK546688/.

Rodriguez-Ayllon, María, Cristina Cadenas-Sánchez, Fernando Estévez-López, Nicolas E. Muñoz, Jose Mora-Gonzalez, Jairo H. Migueles, Pablo Molina-García, et al. 2019. “Role of Physical Activity and Sedentary Behavior in the Mental Health of Preschoolers, Children and Adolescents: A Systematic Review and Meta-Analysis.” *Sports Medicine* 49 (9): 1383–1410. https://doi.org/10.1007/s40279-019-01099-5.

Roe, Mark, Catherine Blake, Conor Gissane, and Kieran Collins. 2016. “Injury Scheme Claims in Gaelic Games: A Review of 2007–2014.” *Journal of Athletic Training* 51 (4): 303–8. https://doi.org/10.4085/1062-6050-51.4.07.

Roe, Mark, Eamonn Delahunt, Malachy McHugh, Conor Gissane, Shane Malone, Kieran Collins, and Catherine Blake. 2020. “Association between Eccentric Knee Flexor Strength and Hamstring Injury Risk in 185 Elite Gaelic Football Players.” *Scandinavian Journal of Medicine & Science in Sports* 30 (3): 515–22. https://doi.org/10.1111/sms.13588.

Roe, Mark, Shane Malone, Catherine Blake, Kieran Collins, Conor Gissane, Fionn Büttner, John C. Murphy, and Eamonn Delahunt. 2017. “A Six Stage Operational Framework for Individualising Injury Risk Management in Sport.” *Injury Epidemiology* 4 (1): 26. https://doi.org/10.1186/s40621-017-0123-x.

Roe, Mark, John C Murphy, Conor Gissane, and Catherine Blake. 2016. “Hamstring Injuries in Elite Gaelic Football: An 8-Year Investigation to Identify Injury Rates, Time-Loss Patterns and Players at Increased Risk.” *British Journal of Sports Medicine* 52 (15): 982–88.

Roe, Mark, John C. Murphy, Conor Gissane, and Catherine Blake. 2018. “Time to Get Our Four Priorities Right: An 8-Year Prospective Investigation of 1326 Player-

Seasons to Identify the Frequency, Nature, and Burden of Time-Loss Injuries in Elite Gaelic Football." *PeerJ* 6 (July): e4895. https://doi.org/10.7717/peerj.4895.
Rogalski, Brent, Brian Dawson, Jarryd Heasman, and Tim J. Gabbett. 2013. "Training and Game Loads and Injury Risk in Elite Australian Footballers." *Journal of Science and Medicine in Sport* 16 (6): 499–503. https://doi.org/10.1016/j.jsams.2012.12.004.
Rogers, Everett M. 1983. *Diffusion of Innovations*. 3rd ed. New York : London: Free Press ; Collier Macmillan.
Roos, Karen G, Erin B Wasserman, Sara L Dalton, Aaron Gray, Aristarque Djoko, Thomas P Dompier, and Zachary Y Kerr. 2016. "Epidemiology of 3825 Injuries Sustained in Six Seasons of National Collegiate Athletic Association Men's and Women's Soccer (2009/2010–2014/2015)." *British Journal of Sports Medicine* 51 (13): 1029–34. https://doi.org/10.1136/bjsports-2015-095718.
Ross, Andrew G., Alex Donaldson, and Roslyn G. Poulos. 2021. "Nationwide Sports Injury Prevention Strategies: A Scoping Review." *Scandinavian Journal of Medicine & Science in Sports* 31 (2): 246–64. https://doi.org/10.1111/sms.13858.
Ruddy, Joshua D, Christopher W Pollard, Ryan G Timmins, Morgan D Williams, Anthony J Shield, and David A Opar. 2018. "Running Exposure Is Associated with the Risk of Hamstring Strain Injury in Elite Australian Footballers." *British Journal of Sports Medicine* 52 (14): 919–28. https://doi.org/10.1136/bjsports-2016-096777.
Ruddy, Joshua D., Anthony J. Shield, Nirav Maniar, Morgan D. Williams, Steven Duhig, Ryan G. Timmins, Jack Hickey, Matthew N. Bourne, and David A. Opar. 2018. "Predictive Modeling of Hamstring Strain Injuries in Elite Australian Footballers." *Medicine & Science in Sports & Exercise* 50 (5): 906–14. https://doi.org/10.1249/MSS.0000000000001527.
Rutter, Harry, Natalie Savona, Ketevan Glonti, Jo Bibby, Steven Cummins, Diane T Finegood, Felix Greaves, et al. 2017. "The Need for a Complex Systems Model of Evidence for Public Health." *The Lancet* 390 (10112): 2602–4. https://doi.org/10.1016/S0140-6736(17)31267-9.
Sadeh, Avi. 2011. "The Role and Validity of Actigraphy in Sleep Medicine: An Update." *Sleep Medicine Reviews* 15 (4): 259–67. https://doi.org/10.1016/j.smrv.2010.10.001.
Samaan, Michael A., Matthew C. Hoch, Stacie I. Ringleb, Sebastian Bawab, and Joshua T. Weinhandl. 2015. "Isolated Hamstrings Fatigue Alters Hip and Knee Joint Coordination during a Cutting Maneuver." *Journal of Applied Biomechanics* 31 (2): 102–10. https://doi.org/10.1123/JAB.2013-0300.
Sanfilippo, Jennifer L., Amy Silder, Marc A. Sherry, Michael J. Tuite, and Bryan C. Heiderscheit. 2013. "Hamstring Strength and Morphology Progression after Return to Sport from Injury." *Medicine & Science in Sports & Exercise* 45 (3): 448–54. https://doi.org/10.1249/MSS.0b013e3182776eff.
Sato, Kengo, Akimoto Nimura, Kumiko Yamaguchi, and Keiichi Akita. 2012. "Anatomical Study of the Proximal Origin of Hamstring Muscles." *Journal of Orthopaedic Science* 17 (5): 614–18. https://doi.org/10.1007/s00776-012-0243-7.
Schache, Anthony G., Tim W. Dorn, Peter D. Blanch, Nicholas A. T. Brown, and Marcus G. Pandy. 2012. "Mechanics of the Human Hamstring Muscles during Sprinting." *Medicine & Science in Sports & Exercise* 44 (4): 647–58. https://doi.org/10.1249/MSS.0b013e318236a3d2.
Schache, Anthony G., Hyung-Joo Kim, David L. Morgan, and Marcus G. Pandy. 2010. "Hamstring Muscle Forces Prior to and Immediately Following an Acute

Sprinting-Related Muscle Strain Injury." *Gait & Posture* 32 (1): 136–40. https://doi.org/10.1016/j.gaitpost.2010.03.006.
Schache, Anthony G, Stephanie J Woodley, Ernest Schilders, John W Orchard, and Kay M Crossley. 2017. "Anatomical and Morphological Characteristics May Explain Why Groin Pain Is More Common in Male than Female Athletes." *British Journal of Sports Medicine* 51 (7): 554–55. https://doi.org/10.1136/bjsports-2016-096945.
Schache, Anthony G., Tim V. Wrigley, Richard Baker, and Marcus G. Pandy. 2009. "Biomechanical Response to Hamstring Muscle Strain Injury." *Gait & Posture* 29 (2): 332–38. https://doi.org/10.1016/j.gaitpost.2008.10.054.
Schlingermann, Brenagh E., Clare A. Lodge, Conor Gissane, and Paula M. Rankin. 2018. "Effects of the Gaelic Athletic Association 15 on Lower Extremity Injury Incidence and Neuromuscular Functional Outcomes in Collegiate Gaelic Games." *Journal of Strength and Conditioning Research* 32 (7): 1993–2001. https://doi.org/10.1519/JSC.0000000000002108.
Schneider, Kathryn J, John J Leddy, Kevin M Guskiewicz, Tad Seifert, Michael McCrea, Noah D Silverberg, Nina Feddermann-Demont, Grant L Iverson, Alix Hayden, and Michael Makdissi. 2017. "Rest and Treatment/Rehabilitation Following Sport-Related Concussion: A Systematic Review." *British Journal of Sports Medicine* 51 (12): 930–34. https://doi.org/10.1136/bjsports-2016-097475.
Serner, Andreas, Andrea Britt Mosler, Johannes L Tol, Roald Bahr, and Adam Weir. 2019. "Mechanisms of Acute Adductor Longus Injuries in Male Football Players: A Systematic Visual Video Analysis." *British Journal of Sports Medicine* 53 (3): 158–64. https://doi.org/10.1136/bjsports-2018-099246.
Sewry, N., E. Verhagen, M. Lambert, W. van Mechelen, J. Marsh, C. Readhead, W. Viljoen, and J. Brown. 2018. "Trends in Time-Loss Injuries during the 2011-2016 South African Rugby Youth Weeks." *Scandinavian Journal of Medicine & Science in Sports* 28 (9): 2066–73. https://doi.org/10.1111/sms.13087.
Shariff, Ah, Y Ashril, and Ma Razif. 2013. "Pattern of Muscle Injuries and Predictors of Return-to-Play Duration among Malaysian Athletes." *Singapore Medical Journal* 54 (10): 587–91. https://doi.org/10.11622/smedj.2013204.
Shill, Isla J., Anu Räisänen, Amanda M. Black, Craig Barden, Carla van den Berg, Carly D. McKay, Stephen W. West, Kati Pasanen, Brent E. Hagel, and Carolyn A. Emery. 2021. "Canadian High School Rugby Coaches Readiness for an Injury Prevention Strategy Implementation: Evaluating a Train-the-Coach Workshop." *Frontiers in Sports and Active Living* 3 (May): 672603. https://doi.org/10.3389/fspor.2021.672603.
Short, Sandra A., Jennifer Reuter, Jerel Brandt, and Martin W. Short. 2004. "The Relationships Among Three Components of Perceived Risk of Injury, Previous Injuries and Gender in Contact Sport Athletes." *The Online Journal of Sports Psychology* 6 (3).
Shovlin, Aidan, Mark Roe, Shane Malone, and Kieran Collins. 2018. "Positional Anthropometric and Performance Profile of Elite Gaelic Football Players." *Journal of Strength and Conditioning Research* 32 (8): 2356–62. https://doi.org/10.1519/JSC.0000000000002071.
Silder, Amy, Bryan C. Heiderscheit, Darryl G. Thelen, Timothy Enright, and Michael J. Tuite. 2008. "MR Observations of Long-Term Musculotendon Remodeling Following a Hamstring Strain Injury." *Skeletal Radiology* 37 (12): 1101–9. https://doi.org/10.1007/s00256-008-0546-0.
Silvers-Granelli, Holly J., Mario Bizzini, Amelia Arundale, Bert R. Mandelbaum, and Lynn Snyder-Mackler. 2018. "Higher Compliance to a Neuromuscular Injury

Prevention Program Improves Overall Injury Rate in Male Football Players." *Knee Surgery, Sports Traumatology, Arthroscopy* 26 (7): 1975–83. https://doi.org/10.1007/s00167-018-4895-5.
Silvers-Granelli, Holly, Bert Mandelbaum, Ola Adeniji, Stephanie Insler, Mario Bizzini, Ryan Pohlig, Astrid Junge, Lynn Snyder-Mackler, and Jiri Dvorak. 2015. "Efficacy of the FIFA 11+ Injury Prevention Program in the Collegiate Male Soccer Player." *The American Journal of Sports Medicine* 43 (11): 2628–37. https://doi.org/10.1177/0363546515602009.
Skazalski, Christopher, Jacek Kruczynski, Martin Aase Bahr, Tone Bere, Rod Whiteley, and Roald Bahr. 2018. "Landing-Related Ankle Injuries Do Not Occur in Plantarflexion as Once Thought: A Systematic Video Analysis of Ankle Injuries in World-Class Volleyball." *British Journal of Sports Medicine* 52 (2): 74–82. https://doi.org/10.1136/bjsports-2016-097155.
Sly, Nicole, Mariam Soomro, Adrienne L Withall, Patricia Cullen, Robin M Turner, and Sharron R Flahive. 2022. "Players', Parents' and Staffs' Perceptions of Injury Prevention Exercise Programmes in Youth Rugby Union." *BMJ Open Sport & Exercise Medicine* 8 (2): e001271. https://doi.org/10.1136/bmjsem-2021-001271.
Small, K., L. R. McNaughton, M. Greig, M. Lohkamp, and R. Lovell. 2009. "Soccer Fatigue, Sprinting and Hamstring Injury Risk." *International Journal of Sports Medicine* 30 (08): 573–78. https://doi.org/10.1055/s-0029-1202822.
Smith, Nigel A., Melinda M. Franettovich Smith, Matthew N. Bourne, Rod S. Barrett, and Julie A. Hides. 2021. "A Prospective Study of Risk Factors for Hamstring Injury in Australian Football League Players." *Journal of Sports Sciences* 39 (12): 1395–1401. https://doi.org/10.1080/02640414.2021.1875613.
Soligard, T., A. Nilstad, K. Steffen, G. Myklebust, I. Holme, J. Dvorak, R. Bahr, and T. E. Andersen. 2010. "Compliance with a Comprehensive Warm-up Programme to Prevent Injuries in Youth Football." *British Journal of Sports Medicine* 44 (11): 787–93. https://doi.org/10.1136/bjsm.2009.070672.
Soligard, Torbjørn, Martin Schwellnus, Juan-Manuel Alonso, Roald Bahr, Ben Clarsen, H Paul Dijkstra, Tim Gabbett, et al. 2016. "How Much Is Too Much? (Part 1) International Olympic Committee Consensus Statement on Load in Sport and Risk of Injury." *British Journal of Sports Medicine* 50 (17): 1030–41. https://doi.org/10.1136/bjsports-2016-096581.
Stares, Jordan, Brian Dawson, Peter Peeling, Jarryd Heasman, Brent Rogalski, Michael Drew, Marcus Colby, Gregory Dupont, and Leanne Lester. 2018. "Identifying High Risk Loading Conditions for In-Season Injury in Elite Australian Football Players." *Journal of Science and Medicine in Sport* 21 (1): 46–51. https://doi.org/10.1016/j.jsams.2017.05.012.
Steffen, Kathrin, Willem H Meeuwisse, Maria Romiti, Jian Kang, Carly McKay, Mario Bizzini, Jiri Dvorak, Caroline Finch, Grethe Myklebust, and Carolyn A Emery. 2013. "Evaluation of How Different Implementation Strategies of an Injury Prevention Programme (FIFA 11+) Impact Team Adherence and Injury Risk in Canadian Female Youth Football Players: A Cluster-Randomised Trial." *British Journal of Sports Medicine* 47 (8): 480–87. https://doi.org/10.1136/bjsports-2012-091887.
Stensø, Joakim, Thor Einar Andersen, and Joar Harøy. 2022. "Adductor Strengthening Programme Is Successfully Adopted but Frequently Modified in Norwegian Male Professional Football Teams: A Cross-Sectional Study." *BMJ Open* 12 (9): e060611. https://doi.org/10.1136/bmjopen-2021-060611.

Stępień, Karolina, Robert Śmigielski, Caroline Mouton, Bogdan Ciszek, Martin Engelhardt, and Romain Seil. 2019. “Anatomy of Proximal Attachment, Course, and Innervation of Hamstring Muscles: A Pictorial Essay.” *Knee Surgery, Sports Traumatology, Arthroscopy* 27 (3): 673–84. https://doi.org/10.1007/s00167-018-5265-z.

Storey, R. N., G. R. Meikle, M. D. Stringer, and S. J. Woodley. 2016. “Proximal Hamstring Morphology and Morphometry in Men: An Anatomic and MRI Investigation.” *Scandinavian Journal of Medicine & Science in Sports* 26 (12): 1480–89. https://doi.org/10.1111/sms.12625.

Strudwick, A, T Reilly, and D Doran. 2002. “Anthropometric and Fitness Profiles of Elite Players in Two Football Codes.” *Journal of Sports Medicine and Physical Fitness* 42 (2): 239–42.

Sugiura, Yusaku, Tomoyuki Saito, Keishoku Sakuraba, Kazuhiko Sakuma, and Eiichi Suzuki. 2008. “Strength Deficits Identified With Concentric Action of the Hip Extensors and Eccentric Action of the Hamstrings Predispose to Hamstring Injury in Elite Sprinters.” *Journal of Orthopaedic & Sports Physical Therapy* 38 (8): 457–64. https://doi.org/10.2519/jospt.2008.2575.

Sullivan, Charles J., Eoin C. Kavanagh, and Stephen J. Eustace. 2020. “Gaelic Sport Injuries.” *Seminars in Musculoskeletal Radiology* 24 (03): 214–26. https://doi.org/10.1055/s-0040-1708872.

Teahan, Calvin, Siobhán O’Connor, and Enda F. Whyte. 2021. “Injuries in Irish Male and Female Collegiate Athletes.” *Physical Therapy in Sport* 51 (September): 1–7. https://doi.org/10.1016/j.ptsp.2021.06.001.

Tee, Jason C., Shaun J. McLaren, and Ben Jones. 2020. “Sports Injury Prevention Is Complex: We Need to Invest in Better Processes, Not Singular Solutions.” *Sports Medicine* 50 (4): 689–702. https://doi.org/10.1007/s40279-019-01232-4.

Terry, Glenn C., and Robert F. LaPrade. 1996. “The Posterolateral Aspect of the Knee: Anatomy and Surgical Approach.” *The American Journal of Sports Medicine* 24 (6): 732–39. https://doi.org/10.1177/036354659602400606.

Thelen, Darryl G., Elizabeth S. Chumanov, Thomas M. Best, Stephen C. Swanson, and Bryan C. Heiderscheit. 2005. “Simulation of Biceps Femoris Musculotendon Mechanics during the Swing Phase of Sprinting.” *Medicine & Science in Sports & Exercise* 37 (11): 1931–38. https://doi.org/10.1249/01.mss.0000176674.42929.de.

Thelen, Darryl G., Elizabeth S. Chumanov, Dina M. Hoerth, Thomas M. Best, Stephen C. Swanson, Li Li, Michael Young, and Bryan C. Heiderscheit. 2005. “Hamstring Muscle Kinematics during Treadmill Sprinting:” *Medicine & Science in Sports & Exercise* 37 (1): 108–14. https://doi.org/10.1249/01.MSS.0000150078.79120.C8.

Thorpe, Robin T., Greg Atkinson, Barry Drust, and Warren Gregson. 2017. “Monitoring Fatigue Status in Elite Team-Sport Athletes: Implications for Practice.” *International Journal of Sports Physiology and Performance* 12 (s2): S2-27-S2-34. https://doi.org/10.1123/ijspp.2016-0434.

Timmins, R., A. Shield, M. Williams, C. Lorenzen, and D. Opar. 2014. “Differences Exist in the Architectural Characteristics of the Biceps Femoris Long Head in Previously Injured Individuals.” *Journal of Science and Medicine in Sport* 18 (December): e143–44. https://doi.org/10.1016/j.jsams.2014.11.147.

Timmins, Ryan G, Matthew N Bourne, Anthony J Shield, Morgan D Williams, Christian Lorenzen, and David A Opar. 2016. “Short Biceps Femoris Fascicles and Eccentric Knee Flexor Weakness Increase the Risk of Hamstring Injury in Elite Football (Soccer): A Prospective Cohort Study.” *British Journal of Sports Medicine* 50 (24): 1524–35. https://doi.org/10.1136/bjsports-2015-095362.

Ulster.GAA.ie. n.d. *Activate GAA Warm-Up*. https://ulster.gaa.ie/pals/resources/activate-warm-up/.

Van Middelkoop, M., J. Kolkman, J. Van Ochten, S. M. A. Bierma-Zeinstra, and B. W. Koes. 2008. "Risk Factors for Lower Extremity Injuries among Male Marathon Runners: Risk Factors for Running Injuries." *Scandinavian Journal of Medicine & Science in Sports* 18 (6): 691–97. https://doi.org/10.1111/j.1600-0838.2007.00768.x.

Van Tiggelen, D, S Wickes, V Stevens, P Roosen, and E Witvrouw. 2008. "Effective Prevention of Sports Injuries: A Model Integrating Efficacy, Efficiency, Compliance and Risk-Taking Behaviour." *British Journal of Sports Medicine* 42 (8): 648–52. https://doi.org/10.1136/bjsm.2008.046441.

Verhagen, Evert. 2012. "If Athletes Will Not Adopt Preventive Measures, Effective Measures Must Adopt Athletes:" *Current Sports Medicine Reports* 11 (1): 7–8. https://doi.org/10.1249/JSR.0b013e318240dabd.

Verhagen, Evert A.L.M., Maartje M. van Stralen, and Willem van Mechelen. 2010. "Behaviour, the Key Factor for Sports Injury Prevention:" *Sports Medicine* 40 (11): 899–906. https://doi.org/10.2165/11536890-000000000-00000.

Verhagen, Evert, Nicol van Dyk, Nicholas Clark, and Ian Shrier. 2018. "Do Not Throw the Baby out with the Bathwater; Screening Can Identify Meaningful Risk Factors for Sports Injuries." *British Journal of Sports Medicine* 52 (19): 1223–24. https://doi.org/10.1136/bjsports-2017-098547.

Vincent, Heather K., Laura Ann Zdziarski, and Kevin R. Vincent. 2015. "Review of Lacrosse-Related Musculoskeletal Injuries in High School and Collegiate Players." *Sports Health: A Multidisciplinary Approach* 7 (5): 448–51. https://doi.org/10.1177/1941738114552990.

Visser, H M de, M Reijman, M P Heijboer, and P K Bos. 2012. "Risk Factors of Recurrent Hamstring Injuries: A Systematic Review." *British Journal of Sports Medicine* 46 (2): 124–30. https://doi.org/10.1136/bjsports-2011-090317.

Waicus, Kelly M., and Bryan W. Smith. 2002. "Eye Injuries in Women's Lacrosse Players:" *Clinical Journal of Sport Medicine* 12 (1): 24–29. https://doi.org/10.1097/00042752-200201000-00008.

Waldén, Markus, Martin Hägglund, and Jan Ekstrand. 2015. "The Epidemiology of Groin Injury in Senior Football: A Systematic Review of Prospective Studies." *British Journal of Sports Medicine* 49 (12): 792–97. https://doi.org/10.1136/bjsports-2015-094705.

Waldén, Markus, Tron Krosshaug, John Bjørneboe, Thor Einar Andersen, Oliver Faul, and Martin Hägglund. 2015. "Three Distinct Mechanisms Predominate in Non-Contact Anterior Cruciate Ligament Injuries in Male Professional Football Players: A Systematic Video Analysis of 39 Cases." *British Journal of Sports Medicine* 49 (22): 1452–60. https://doi.org/10.1136/bjsports-2014-094573.

Wallace, Jessica, Tracey Covassin, and Erica Beidler. 2017. "Sex Differences in High School Athletes' Knowledge of Sport-Related Concussion Symptoms and Reporting Behaviors." *Journal of Athletic Training* 52 (7): 682–88. https://doi.org/10.4085/1062-6050-52.3.06.

Wangensteen, Arnlaug, Johannes L. Tol, Erik Witvrouw, Robbart Van Linschoten, Emad Almusa, Bruce Hamilton, and Roald Bahr. 2016. "Hamstring Reinjuries Occur at the Same Location and Early After Return to Sport: A Descriptive Study of MRI-Confirmed Reinjuries." *The American Journal of Sports Medicine* 44 (8): 2112–21. https://doi.org/10.1177/0363546516646086.

Warburton, Darren. E.R., Crystal Whitney, Nicol, and Shannon S.D. Bredin. 2006. “Health Benefits of Physical Activity: The Evidence.” *Canadian Medical Association Journal* 174 (6): 801–9. https://doi.org/10.1503/cmaj.051351.
Watson, Anthony W. S. 1996. “Sports Injuries in the Game of Hurling: A One-Year Prospective Study.” *The American Journal of Sports Medicine* 24 (3): 323–28. https://doi.org/10.1177/036354659602400313.
Whalan, Matthew, Ric Lovell, Robert McCunn, and John A. Sampson. 2019. “The Incidence and Burden of Time Loss Injury in Australian Men’s Sub-Elite Football (Soccer): A Single Season Prospective Cohort Study.” *Journal of Science and Medicine in Sport* 22 (1): 42–47. https://doi.org/10.1016/j.jsams.2018.05.024.
White, Peta E, Leonie Otago, Natalie Saunders, Maria Romiti, Alex Donaldson, Shahid Ullah, and Caroline F Finch. 2014. “Ensuring Implementation Success: How Should Coach Injury Prevention Education Be Improved If We Want Coaches to Deliver Safety Programmes during Training Sessions?: Table 1.” *British Journal of Sports Medicine* 48 (5): 402–3. https://doi.org/10.1136/bjsports-2012-091987.
Whyte, Enda F., Brian Heneghan, Kevin Feely, Kieran A. Moran, and Siobhán O’Connor. 2021. “The Effect of Hip Extension and Nordic Hamstring Exercise Protocols on Hamstring Strength: A Randomized Controlled Trial.” *Journal of Strength and Conditioning Research* 35 (10): 2682–89. https://doi.org/10.1519/JSC.0000000000003220.
Wilke, J., D. Niederer, L. Vogt, and W. Banzer. 2018. “Head Coaches’ Attitudes towards Injury Prevention and Use of Related Methods in Professional Basketball: A Survey.” *Physical Therapy in Sport* 32 (July): 133–39. https://doi.org/10.1016/j.ptsp.2018.04.011.
Wilke, Jan, Daniel Niederer, Lutz Vogt, and Winfried Banzer. 2018. “Is the Message Getting through? Awareness and Use of the 11+ Injury Prevention Programme in Amateur Level Football Clubs.” Edited by Antoine Nordez. *PLOS ONE* 13 (4): e0195998. https://doi.org/10.1371/journal.pone.0195998.
Wille, Christa M., Mikel R. Stiffler-Joachim, Stephanie A. Kliethermes, Jennifer L. Sanfilippo, Claire S. Tanaka, and Bryan C. Heiderscheit. 2022. “Preseason Eccentric Strength Is Not Associated with Hamstring Strain Injury: A Prospective Study in Collegiate Athletes.” *Medicine & Science in Sports & Exercise* 54 (8): 1271–77. https://doi.org/10.1249/MSS.0000000000002913.
Williams, Sean, Grant Trewartha, Simon P T Kemp, John H M Brooks, Colin W Fuller, Aileen E Taylor, Matthew J Cross, and Keith A Stokes. 2016. “Time Loss Injuries Compromise Team Success in Elite Rugby Union: A 7-Year Prospective Study.” *British Journal of Sports Medicine* 50 (11): 651–56. https://doi.org/10.1136/bjsports-2015-094798.
Williams, Sean, Grant Trewartha, Simon Kemp, and Keith Stokes. 2013. “A Meta-Analysis of Injuries in Senior Men’s Professional Rugby Union.” *Sports Medicine* 43 (10): 1043–55. https://doi.org/10.1007/s40279-013-0078-1.
Wilson, F, S Caffrey, E King, K Casey, and C Gissane. 2007. “A 6-Month Prospective Study of Injury in Gaelic Football.” *British Journal of Sports Medicine* 41 (5): 317–21. https://doi.org/10.1136/bjsm.2006.033167.
Windt, Johann, and Tim J Gabbett. 2017. “How Do Training and Competition Workloads Relate to Injury? The Workload—Injury Aetiology Model.” *British Journal of Sports Medicine* 51 (5): 428–35. https://doi.org/10.1136/bjsports-2016-096040.
Wisbey, Ben, Paul G. Montgomery, David B. Pyne, and Ben Rattray. 2010. “Quantifying Movement Demands of AFL Football Using GPS Tracking.” *Journal of Science*

and Medicine in Sport 13 (5): 531–36. https://doi.org/10.1016/j.jsams.2009.09.002.
Witvrouw, Erik, Lieven Danneels, Peter Asselman, Thomas D'Have, and Dirk Cambier. 2003. "Muscle Flexibility as a Risk Factor for Developing Muscle Injuries in Male Professional Soccer Players: A Prospective Study." *The American Journal of Sports Medicine* 31 (1): 41–46. https://doi.org/10.1177/03635465030310011801.
Wojtys, Edward M., Laura J. Huston, Melbourne D. Boynton, Kurt P. Spindler, and Thomas N. Lindenfeld. 2002. "The Effect of the Menstrual Cycle on Anterior Cruciate Ligament Injuries in Women as Determined by Hormone Levels." *The American Journal of Sports Medicine* 30 (2): 182–88. https://doi.org/10.1177/03635465020300020601.
Woodley, Stephanie J., and Susan R. Mercer. 2005. "Hamstring Muscles: Architecture and Innervation." *Cells Tissues Organs* 179 (3): 125–41. https://doi.org/10.1159/000085004.
Woods, C, R D Hawkins, S Maltby, M Hulse, A Thomas, and A Hodson. 2004. "The Football Association Medical Research Programme: An Audit of Injuries in Professional Football--Analysis of Hamstring Injuries." *British Journal of Sports Medicine* 38 (1): 36–41. https://doi.org/10.1136/bjsm.2002.002352.
World.Rugby. n.d. *The Tackle*. https://www.world.rugby/the-game/beginners-guide/tackle.
Worrell, Teddy W., and David H. Perrin. 1992. "Hamstring Muscle Injury: The Influence of Strength, Flexibility, Warm-Up, and Fatigue." *Journal of Orthopaedic & Sports Physical Therapy* 16 (1): 12–18. https://doi.org/10.2519/jospt.1992.16.1.12.
Worth, David R. 1969. "The Hamstring Injury in Australian Rules Football." *Australian Journal of Physiotherapy* 15 (3): 111–13. https://doi.org/10.1016/S0004-9514(14)61080-1.
Yeomans, Caithriona, Ian C. Kenny, Roisin Cahalan, Giles D. Warrington, Andrew J. Harrison, Kevin Hayes, Mark Lyons, Mark J. Campbell, and Thomas M. Comyns. 2018. "The Incidence of Injury in Amateur Male Rugby Union: A Systematic Review and Meta-Analysis." *Sports Medicine* 48 (4): 837–48. https://doi.org/10.1007/s40279-017-0838-4.
Yeomans, Caithriona, Ian C. Kenny, Roisin Cahalan, Giles D. Warrington, Andrew J. Harrison, Helen Purtill, Mark Lyons, Mark J. Campbell, Liam G. Glynn, and Thomas M. Comyns. 2021. "Injury Trends in Irish Amateur Rugby: An Epidemiological Comparison of Men and Women." *Sports Health: A Multidisciplinary Approach*, March, 194173812199714. https://doi.org/10.1177/1941738121997145.
Young, Damien, Giuseppe Coratella, Shane Malone, Kieran Collins, Laurent Mourot, and Marco Beato. 2019. "The Match-Play Sprint Performance of Elite Senior Hurlers during Competitive Games." Edited by Luca Paolo Ardigò. *PLOS ONE* 14 (4): e0215156. https://doi.org/10.1371/journal.pone.0215156.
Young, Damien, Shane Malone, Kieran Collins, Laurent Mourot, Marco Beato, and Giuseppe Coratella. 2019. "Metabolic Power in Hurling with Respect to Position and Halves of Match-Play." Edited by Moacir Marocolo. *PLOS ONE* 14 (12): e0225947. https://doi.org/10.1371/journal.pone.0225947.
Young, Damien, Laurent Mourot, Marco Beato, and Giuseppe Coratella. 2018. "The Match Heart Rate and Running Profile of Elite Under-21 Hurlers During Competitive Match-Play." *Journal of Strength and Conditioning Research* 32 (10): 2925–33. https://doi.org/10.1519/JSC.0000000000002558.

———. 2020. “Match-Play Demands of Elite U17 Hurlers During Competitive Matches.” *Journal of Strength and Conditioning Research* 34 (7): 1982–89. https://doi.org/10.1519/JSC.0000000000002945.

Young, Damien, Laurent Mourot, and Giuseppe Coratella. 2018. “Match-Play Performance Comparisons between Elite and Sub-Elite Hurling Players.” *Sport Sciences for Health* 14 (1): 201–8. https://doi.org/10.1007/s11332-018-0441-6.

Young, Damien, Maggie O’Grady, and Giuseppe Coratella. 2021. “The Match-Play Running Performance of Elite Camogie Players across Halves of Play.” *Sport Sciences for Health* 17 (1): 191–99. https://doi.org/10.1007/s11332-020-00672-0.

Yu, Bing, Hui Liu, and William E. Garrett. 2017. “Mechanism of Hamstring Muscle Strain Injury in Sprinting.” *Journal of Sport and Health Science* 6 (2): 130–32. https://doi.org/10.1016/j.jshs.2017.02.002.

Zech, Astrid, Karsten Hollander, Astrid Junge, Simon Steib, Andreas Groll, Jonas Heiner, Florian Nowak, Daniel Pfeiffer, and Anna Lina Rahlf. 2022. “Sex Differences in Injury Rates in Team-Sport Athletes: A Systematic Review and Meta-Regression Analysis.” *Journal of Sport and Health Science* 11 (1): 104–14. https://doi.org/10.1016/j.jshs.2021.04.003.

Zech, Astrid, and Kai Wellmann. 2017. “Perceptions of Football Players Regarding Injury Risk Factors and Prevention Strategies.” Edited by Fernando de Castro. *PLOS ONE* 12 (5): e0176829. https://doi.org/10.1371/journal.pone.0176829.

Appendices

Appendix A

Injury Record Form

1. Name ______________ **DOB** ______________
Contact No ______________ **Team** ______________
Assessed By ______________________________
Date of Injury ______________________________
Av. hours training per week____Av. hours matches per week_____
No. of trainings per week_____No. of matches per week________

2. Sport injured in
□ Gaelic Football □ Hurling □ Camogie
□ Soccer □ Rugby □ Athletics
□ Basketball □ Handball □ Other ___________

3. Position
□ Goalkeeper □ Back □ Midfield
□ Forward □ Substitute

4. Injury occurred with
□ Club team □ Collegiate team
□ County team □ Recreational team
□ Work team □ Individual activity
□ Representative team (if other sport)

5. Injury occurred during
□ Preseason □ Regular season □ Off season

6. Onset of injury
□ Gradual onset, no specific time □ Sudden onset

7. Injury occurred during (pick one only)
□ Team outdoor training □ Team indoor training
□ Friendly game □ Competitive game
□ Dead ball kicking session □ Specific skills session
□ Individual activity □ Gradual onset

8. Type of playing surface
□ Grass □ Synthetic □ Indoor □ Track
□ Road □ Beach □ Other__________

9. Time of injury
□ Warm up □ Cool down □ Min of match/training______

10. Type of injury
□ New injury □ Early recurrence (<1 month)
□ Late recurrence (2-12 months) □ Persistent / recurring

11. Side of injury
□ Left □ Right □ Bilateral □ Trunk

12. Contact injury?
□ Yes □ No

13. Specific nature of injury
____

14. Injury mechanism - Contact with:
□ Other player □ Playing surface □ Football
□ Apparatus □ Goal-post □ Flag
□ Hurley □ Sliothar □ Helmet
□ other person (non-player) □ Non-contact
□ Assault/violence □ Gradual onset (overuse)
□ Equipment/clothing (e.g friction burn / blister)
□ Other ______________________

15. Activity during injury
□ Jumping/catching □ Landing □ Turning
□ Running/sprinting □ Kicking □ Diving
□ Hand pass □ Stopping □ Falling
□ Tackling □ Being tackled □ Blocking
□ Dead ball kick/puck □ Punching ball □ Hooking
□ Pushing/shoving □ Catching
□ No specific activity

16. Body part injured
□ Toes □ Foot □ Ankle □ Shin □ Calf
□ Knee □ Anterior Thigh □ Posterior Thigh
□ Groin □ Hip □ Buttock □ Pelvis □ Lumbar
□ Thoracic □ Neck □ Chest □ Stomach □ Head
□ Face □ Eye □ Ear □ Mouth □ Shoulder
□ Upper arm □ Elbow □ Forearm □Wrist
□ Hand □ Fingers □ Thumb □ Other__________

17. Structure injured
□ Ligament □ Muscle □ Bone □ Tendon
□ Nerve □ Cartilage □ Meniscus □ Labrum
□ Other______________________________

18. Type of injury
□ Sprain □ Strain □ Contusion □ Tendinopathy
□ Fracture □ Dislocation □ Stress fracture
□ Compartment syndrome □ Shin splints □ Laceration
□ Concussion □ Dental injury □ Bone bruise
□ Muscle tightness □ Neural □ Cartilage/labrum tear
□ Other______________________________

19. Were you wearing Protective equipment/taping?
□ Mouthguard □ Helmet
□ Taping ______________________________
□ Bracing ______________________________
□ Other ______________________________

20. Referee's sanction
□ No foul □ Opponent foul □ Own foul □ N/A

21. Injury assessment
Examination by
□ Doctor □ ATT/ARTC □ Physiotherapist
□ Chiropractor □ Physical Therapist □ Osteopath
□ Other __________________

22. Imaging for current injury
□ X-Ray □ MRI □ CAT
□ Bone Scan □ Diagnostic Ultrasound □ None
□ Other __________________________

23. Did this injury require surgery?
□ Yes during season □ Yes, post season □ No

24. Dates
Date of injury _____________
Date of completing this form _____________
Days until resuming light training _____________
Days until resuming full training (unable to play) _______
Days until Full fitness (able to play and train) ________

Appendix B

KERRY PRESEASON SCREENING FORM

Name: ______________________________

DOB: ______________

Current Training Status:
Who:

What:

When:

Injury History:
Current:

Past12mths:

Previous:

Any Previous Surgeries:

Medical History:
Current medications (inhalers etc.):

Strappings:

Appendix C

If you are happy to proceed with the questionnaire, please select the box below to indicate your consent to the research.

○ I consent

Q2 Do you identify primarily as a Gaelic games coach or player?

○ Coach

○ Player

Q3 What is your gender?

○ Male

○ Female

○ Non-binary/ third gender

○ Prefer not to say

Q4 What age are you currently in years?

▼ 18 ... 85

Q5 What field-based Gaelic games code do you coach or play? (Please tick all that apply)

▢ Gaelic football

▢ Hurling

▢ Ladies Gaelic football

▢ Camogie

Display This Question:

If Do you identify primarily as a Gaelic games coach or player? = Coach

Q6 How many years coaching experience do you have?

▼ less than 1 year ... 49 years

Display This Question:

If Do you identify primarily as a Gaelic games coach or player? = Player

Q7 How many years playing experience do you have?

▼ less than 1 year ... 35 years

Display This Question:

If Do you identify primarily as a Gaelic games coach or player? = Coach

Q8 What is the highest level of participation that you are currently coaching at? (Please pick one answer)

○ Juvenile U4-U6 (F1)

○ Juvenile U7-U12 (F2)

○ Juvenile club U12+ (F3)

○ Junior club (F3)

◯ Intermediate club (F3)

◯ Senior club (F3)

◯ Junior schools U13-U14 (T1)

◯ Development/Academy county squad U13-U14 (T1)

◯ Junior schools U15-U16 (T2)

◯ Development/Academy county squad U15-U16 (T2)

◯ Senior school U17-U19 (T3)

◯ Collegiate freshers U17-U19 (T3)

◯ Intercounty minor (T3)

◯ Intercounty U20s (T3/T4)

◯ Collegiate senior U20-U23 (T4)

◯ Senior Intercounty (E1)

Display This Question:
If Do you identify primarily as a Gaelic games coach or player? = Player
Q9 What is the highest level of participation that you are currently playing at (please pick one answer)?

◯ Junior club (F3)

◯ Intermediate club (F3)

◯ Senior club (F3)

◯ Senior school U17-U19 (T3)

◯ Collegiate freshers U17-U19 (T3)

◯ Intercounty minor (T3)

◯ Intercounty U20s (T3/T4)

◯ Collegiate senior U20-U23 (T4)

◯ Senior Intercounty (E1)

Display This Question:
If Do you identify primarily as a Gaelic games coach or player? = Coach
Q10 Have you completed any coaching qualifications? (Please tick all that apply)

▢ Camogie Foundation Course

▢ Camogie Level 1

☐ Camogie Level 2

☐ GAA Foundation Award

☐ GAA Award 1 Coach Education

☐ GAA Award 2 Coach Education

☐ LGFA FUNdamentals Course

☐ LGFA Level 1

☐ FAI Kick Start 1

☐ FAI Kick Start 2

☐ IRFU- Mini Rugby

☐ IRFU- Foundation Level

☐ IRFU- Level 1

☐ IRFU- Level 2

☐ IRFU- Level 3

☐ No

☐ Other (Please state) ____

Skip To: Q12 If Have you completed any coaching qualifications? (Please tick all that apply) = No
Display This Question:
If Do you identify primarily as a Gaelic games coach or player? = Coach

Q11 When was your most recent coaching qualification attained?
▼ less than 1 year ... 20 years

Q12 In which county is your club located?
▼ Antrim ... Outside of Ireland

Q13 Does your team regularly have access to an athletic development coach (fitness/S&C coach)?

- ◯ Yes
- ◯ No

Q14 Does your team have access to an Athletic therapist/Physiotherapist?

- ◯ Every training and match
- ◯ Every match only
- ◯ Championship matches only
- ◯ Every training only
- ◯ One training a week only
- ◯ One training a week and every match
- ◯ Occasional
- ◯ Never

Q15 Does your team conduct preseason screening (a battery of physical assessment tests) aiming to evaluate injury risk?

- ◯ Yes
- ◯ No
- ◯ Unsure (please give further detail) ________________________________

Skip To: Q19 If Does your team conduct preseason screening (a battery of physical assessment tests) aiming to eva... = No
Display This Question:
If Do you identify primarily as a Gaelic games coach or player? = Coach
Q16 Who is responsible for the delivery of the preseason screening for your team? (Please tick all that apply)

- ☐ Coach (me)
- ☐ Coach (other)
- ☐ Athletic development coach (fitness/S&C coach)
- ☐ Athletic therapist/Physiotherapist
- ☐ External group outside my team setup
- ☐ Other (please state) ____

Display This Question:
If Do you identify primarily as a Gaelic games coach or player? = Player
Q17 Who is responsible for the delivery of the preseason screening for your team? (Please tick all that apply)

- ☐ Coach (main)
- ☐ Coach (other)
- ☐ Athletic development coach (fitness/S&C coach)
- ☐ Athletic therapist/Physiotherapist
- ☐ External group outside my team setup
- ☐ Other (please state) ____

Q18 Which of the following tests/methods, is used with your team? (Please tick all that apply)

- ☐ Functional Movement Screen (FMS)
- ☐ Y-balance/Star Excursion balance test
- ☐ Strength testing
- ☐ Flexibility measurements
- ☐ Bilateral (double leg) jump testing
- ☐ Unilateral (single leg) jump testing
- ☐ Medical/Injury history
- ☐ Concussion testing
- ☐ Cardiorespiratory endurance testing
- ☐ Don't know
- ☐ Other (please state)

____

Q19 Please rank the 5 most important injuries to prevent (from most important to prevent to least important to prevent)?

Ankle injuries
Achilles injuries
Calf injuries
Anterior Cruciate Ligament injuries (ACL)
Other knee ligament injuries
Hamstring injuries (back of thigh)
Quadriceps injuries (front of thigh)
Hip/Groin Injuries
Low back injuries
Rotator cuff injuries (muscle/tendon injury around the shoulder)
Shoulder ligament injuries (e.g. dislocation AC joint sprain)
Concussion
Hand injuries

Q20 How effective do you rate the following interventions for injury prevention in Gaelic games? Please select one answer that best fits your opinion (scale from 1 not effective at all to 10 extremely effective).

	Not effective at all		Slightly effective		Moderately effective		Very effective		Extremely effective	
	1	2	3	4	5	6	7	8	9	10
Activation exercises (e.g. mini band)										
Active recovery										

Adequate sleep
Agility training (e.g. starting, stopping, cutting)
Balance training
Compression garments
Cool-down jog/run
Core stability training
Cryotherapy (e.g. ice baths)
Education (e.g. images/videos)
Endurance training
Foam rolling
Good nutrition
Knowledge of the rules
Load management
Massage
Orthoses (e.g. insoles)
Plyometric training (e.g. skipping, hopping, bounding)
Recovery boots
Resistance training
Speed training
Stretching
Taping/Strapping/Bracing
Training of functional movement patterns (How well a person moves)
Training of landing technique
Training proper sport technique
Warm up jog/run

Q21 Which of the following injury prevention measures do you use with your team for injury prevention in Gaelic games?

	Never	Sometimes	About half the time	Most of the time	Always
Activation exercises (e.g. mini band)	○	○	○	○	○
Active recovery	○	○	○	○	○
Adequate sleep	○	○	○	○	○
Agility training (e.g. starting, stopping, cutting)	○	○	○	○	○

Balance training	○	○	○	○	○
Compression garments	○	○	○	○	○
Cool-down jog/run	○	○	○	○	○
Core stability training	○	○	○	○	○
Cryotherapy (e.g. ice baths)	○	○	○	○	○
Education (e.g. images/videos)	○	○	○	○	○
Endurance training	○	○	○	○	○
Foam rolling	○	○	○	○	○
Good nutrition	○	○	○	○	○
Knowledge of the rules	○	○	○	○	○
Load management	○	○	○	○	○
Massage	○	○	○	○	○
Orthoses (e.g. insoles)	○	○	○	○	○
Plyometric training (e.g. skipping, hopping, bounding)	○	○	○	○	○
Recovery boots	○	○	○	○	○
Resistance training	○	○	○	○	○
Speed training	○	○	○	○	○
Stretching	○	○	○	○	○
Taping/Strapping/Bracing	○	○	○	○	○
Training of functional movement patterns (How well a person moves)	○	○	○	○	○
Training of landing technique	○	○	○	○	○

Training proper sport technique	○	○	○	○	○
Warm up jog/run	○	○	○	○	○

Q22 Are you aware of any specific injury prevention exercise programme(s) for Gaelic games?

- ○ Yes
- ○ No

Skip To: Q24 If Are you aware of any specific injury prevention exercise programme(s) for Gaelic games? = No

Q23 Can you please name the Gaelic games injury prevention exercise programme(s) you are aware of?

____

Q24 Do you use injury prevention exercise programmes with your team (e.g. GAA 15, Activate GAA Warm-up)?

- ○ Yes
- ○ No
- ○ Unsure

Skip To: Q30 If Do you use injury prevention exercise programmes with your team (e.g. GAA 15, Activate GAA Warm-up)? = No

Q25 What injury prevention exercise programme(s) are you using? (Please tick all that apply)

- ▢ GAA 15
- ▢ Activate GAA Warm-up
- ▢ The Athletic Development and Injury Prevention Warm Up
- ▢ Camogie Injury Prevention Programme
- ▢ Modified injury prevention exercise programme
- ▢ An injury prevention exercise programme I developed myself
- ▢ Other (please state) ____

Display This Question:

If Do you identify primarily as a Gaelic games coach or player? = Coach

Q26 Who is responsible for the delivery of an injury prevention exercise programme with your team? (Please tick all that apply)

- ☐ Coach (me)
- ☐ Coach (other)
- ☐ Athletic development coach (fitness/S&C coach)
- ☐ Athletic therapist/Physiotherapist
- ☐ Player led during training
- ☐ Player self-administered outside of training time

Display This Question:
If Do you identify primarily as a Gaelic games coach or player? = Player

Q27 Who is responsible for the delivery of an injury prevention exercise programme with your team? (Please tick all that apply)

- ☐ Coach (head)
- ☐ Coach (other)
- ☐ Athletic development coach (fitness/S&C coach)
- ☐ Athletic therapist/Physiotherapist
- ☐ Player led during training
- ☐ Player self-administered outside of training time

Q28 How often are injury prevention exercise programmes carried out by your team (tick one answer)?

- ○ Every training
- ○ Every match
- ○ Every training and every match
- ○ One training a week
- ○ Less than one training/match a week
- ○ Player completed outside of training and match time

◯ Never

◯ Other (Please state)

____

Q29 How long in each session does your team spend implementing injury prevention exercise programmes (tick one answer)?

◯ None

◯ 1 to 5 minutes

◯ 6 to 10 minutes

◯ 11 to 15 minutes

◯ 16 to 20 minutes

◯ > 20 minutes

Skip To: Q31 If How long in each session does your team spend implementing injury prevention exercise programmes... = 1 to 5 minutes
Skip To: Q31 If How long in each session does your team spend implementing injury prevention exercise programmes... = 6 to 10 minutes
Skip To: Q31 If How long in each session does your team spend implementing injury prevention exercise programmes... = 11 to 15 minutes
Skip To: Q31 If How long in each session does your team spend implementing injury prevention exercise programmes... = 16 to 20 minutes
Skip To: Q31 If How long in each session does your team spend implementing injury prevention exercise programmes... = > 20 minutes

Q30 Why do you not use an injury prevention exercise programme with your team?

▢ Lack of confidence

▢ Lack of skill level

▢ Lack of time

▢ Lack of resources

▢ Lack of equipment

▢ Other (please state)

____

Q31 Do you think injury prevention exercise programmes are effective at preventing injuries?

- ◯ Yes
- ◯ No
- ◯ Unsure (please give further detail)

____

Q32 Do you think that injury prevention exercise programmes can improve performance?

- ◯ Yes
- ◯ No
- ◯ Unsure (please give further detail)

____

:

Q33 What are the elements of injury prevention exercise programme your team uses? (Please tick all that apply)

- ▢ Running
- ▢ Muscle activation exercises
- ▢ Muscle strengthening exercises
- ▢ Flexibility/Mobility
- ▢ Balance exercise
- ▢ Jumping and landing mechanics
- ▢ Change of direction exercises/ Agility
- ▢ Preparation for contact (contact primers)
- ▢ Acceleration
- ▢ Deceleration
- ▢ Sprinting

Display This Question:

If Do you identify primarily as a Gaelic games coach or player? = Coach

Q34 Please respond to the following statements regarding injuries and injury prevention exercise programmes. Please select one answer that best fits your opinion (strongly agree, agree, neither agree nor disagree, disagree, strongly disagree).

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Injuries are an issue with my team	○	○	○	○	○
Injuries can shorten a player's career	○	○	○	○	○
Injuries can cause physical problems later in life	○	○	○	○	○
Injuries have a negative impact on team performance	○	○	○	○	○
Gaelic games players are at a high risk of suffering an injury	○	○	○	○	○
I believe that it is safe to play with injuries	○	○	○	○	○
I am willing to let my players play with injuries	○	○	○	○	○
I believe that players should be fully rehabilitated before playing again after they have suffered an injury	○	○	○	○	○
I admire Gaelic games players who continue to play when they are injured	○	○	○	○	○
I supports players when they are injured	○	○	○	○	○
The club assists players with medical assistance/rehabilitation when they are injured	○	○	○	○	○
Injury prevention programmes cost too much	○	○	○	○	○
Injury prevention programmes takes up too much training time away from other tasks	○	○	○	○	○
It's important for coaches to have current knowledge of injury prevention programmes	○	○	○	○	○
It's important for players to have current knowledge of injury prevention programmes	○	○	○	○	○

Injury prevention is important during training sessions	○	○	○	○	○
Activities included in injury prevention programmes are relevant and beneficial to players	○	○	○	○	○
I believe that using an injury prevention programme will reduce the number of injuries for my team	○	○	○	○	○
I believe that injuries are preventable	○	○	○	○	○
Exercises which have been shown to prevent injuries should be performed by Gaelic games players	○	○	○	○	○
Exercises to prevent injuries should be varied and progressed over time	○	○	○	○	○

Display This Question:
If Do you identify primarily as a Gaelic games coach or player? = Player

Q35 Please respond to the following statements regarding injuries and injury prevention exercise programmes. Please select one answer that best fits your opinion (strongly agree, agree, neither agree nor disagree, disagree, strongly disagree).

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Injuries are an issue with my team	○	○	○	○	○
Injuries can shorten a player's career	○	○	○	○	○
Injuries can cause physical problems later in life	○	○	○	○	○
Injuries have a negative impact on team performance	○	○	○	○	○
Gaelic games players are at a high risk of suffering an injury	○	○	○	○	○
I believe that it is safe to play with injuries	○	○	○	○	○
I am willing to play with injuries	○	○	○	○	○
I believe that players should be fully rehabilitated before playing again after they have suffered an injury	○	○	○	○	○

I admire Gaelic games players who continue to play when they are injured	○	○	○	○	○
The coach supports me when I am injured	○	○	○	○	○
The club assists me with medical assistance/rehabilitation when I am injured	○	○	○	○	○
I feel under pressure to play when I am injured	○	○	○	○	○
Injury prevention programmes cost too much	○	○	○	○	○
Injury prevention programmes takes up too much training time away from other tasks	○	○	○	○	○
It's important for coaches to have current knowledge of injury prevention programmes	○	○	○	○	○
It's important for players to have current knowledge of injury prevention programmes	○	○	○	○	○
Injury prevention is important during training sessions	○	○	○	○	○
Activities included in injury prevention programmes are relevant and beneficial to players	○	○	○	○	○
I believe that using an injury prevention programme will reduce the number of injuries for my team	○	○	○	○	○
I believe that injuries are preventable	○	○	○	○	○
Exercises which have been shown to prevent injuries should be performed by Gaelic games players	○	○	○	○	○
Exercises to prevent injuries should be varied and progressed over time	○	○	○	○	○

Display This Question:
If Do you identify primarily as a Gaelic games coach or player? = Coach

Q36 Please rate the following statements with regards to barriers to the implementation of injury prevention exercise programmes. Please select one answer that best fits your opinion (strongly agree, agree, neither agree nor disagree, disagree, strongly disagree).

	Strongly disagree	Disagree	Neither agree	Agree	Strongly agree

			nor disagree		
My team's training sessions are not long enough to devote time to injury prevention	○	○	○	○	○
The injury prevention exercise programme is too long	○	○	○	○	○
I find exercises too difficult	○	○	○	○	○
I find the exercises boring	○	○	○	○	○
The programme is too rigid/structured	○	○	○	○	○
I am not motivated enough	○	○	○	○	○
There is no ball/hurley involved	○	○	○	○	○
There is no training available to teach me about injury prevention exercise programmes	○	○	○	○	○
I do not believe that using an injury prevention exercise programme will actually reduce the number of injuries on my team	○	○	○	○	○
My team does not have anyone with appropriate skill and knowledge to implement an injury prevention exercise programme	○	○	○	○	○
The programmes cause soreness and this impacts subsequent training session performance	○	○	○	○	○
The motivation of the coach affects the players' motivation to do injury prevention exercises	○	○	○	○	○
I do not have enough knowledge on how to use it	○	○	○	○	○
I am not sure if injury prevention is beneficial to the team	○	○	○	○	○

Display This Question:
If Do you identify primarily as a Gaelic games coach or player? = Player
Q37 Please rate the following statements with regards to barriers to the implementation of injury prevention exercise programmes. Please select one answer that best fits your opinion (strongly agree, agree, neither agree nor disagree, disagree, strongly disagree).

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
My team's training sessions are not long enough to devote time to injury prevention	○	○	○	○	○
The injury prevention exercise programme is too long	○	○	○	○	○
I find exercises too difficult	○	○	○	○	○
I find the exercises boring	○	○	○	○	○
The programme is too rigid/structured	○	○	○	○	○
I am not motivated enough	○	○	○	○	○
There is no ball/hurley involved	○	○	○	○	○
There is no training available to teach me about injury prevention exercise programmes	○	○	○	○	○
I do not believe that using an injury prevention exercise programme will actually reduce the number of injuries on my team	○	○	○	○	○
My team does not have anyone with appropriate skill and knowledge to implement an injury prevention exercise programme	○	○	○	○	○
The programmes cause soreness and this impacts subsequent training session performance	○	○	○	○	○
I do not have a history of injury	○	○	○	○	○
The motivation of the coach affects the players' motivation to do injury prevention exercises	○	○	○	○	○
I do not have enough knowledge on how to use it	○	○	○	○	○
My coach does not have enough knowledge on how to use it	○	○	○	○	○
I am not sure if injury prevention is beneficial to the team	○	○	○	○	○

My coach is not sure if injury prevention is beneficial is to the team	○	○	○	○	○

Display This Question:
If Do you identify primarily as a Gaelic games coach or player? = Coach

Q38 Please rate the following statements with regards to facilitators to the implementation of injury prevention exercise programmes. Please select one answer that best fits your opinion (strongly agree, agree, neither agree nor disagree, disagree, strongly disagree).

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Observing elite teams and players doing the exercises would encourage me to complete an injury prevention exercise programme	○	○	○	○	○
Better resources (videos, apps, printed material webinars, courses) would encourage me to complete an injury prevention exercise programme	○	○	○	○	○
More training in delivery of the programme would encourage me to complete an injury prevention exercise programme	○	○	○	○	○
The introduction of a ball or skills training into the programme would encourage me to complete an injury prevention exercise programme	○	○	○	○	○
A player in your team having a serious injury during a game or training would encourage me to complete an injury prevention exercise programme	○	○	○	○	○
I would be willing to perform an injury prevention exercise programme if data proved players would run faster	○	○	○	○	○
I would be willing to perform an injury prevention exercise programme if data proved player would jump higher	○	○	○	○	○
I would be willing to perform an injury prevention exercise programme if data proved I would have fewer injury risk factors when I move	○	○	○	○	○
I would feel comfortable leading my team in an injury prevention exercise programme	○	○	○	○	○

I would feel comfortable with a a player leading my team in an injury prevention exercise programme	○	○	○	○	○
I would feel comfortable with another coach leading my team in an injury prevention exercise programme	○	○	○	○	○
I would feel comfortable with my athletic development coach (fitness/S&C coach) leading my team in an injury prevention exercise programme	○	○	○	○	○
I would feel comfortable with my athletic therapist/physiotherapist leading my team in an injury prevention exercise programme	○	○	○	○	○

Display This Question:
If Do you identify primarily as a Gaelic games coach or player? = Player

Q39 Please rate the following statements with regards to facilitators to the implementation of injury prevention exercise programmes. Please select one answer that best fits your opinion (strongly agree, agree, neither agree nor disagree, disagree, strongly disagree).

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Observing elite teams and players doing the exercises would encourage me to complete an injury prevention exercise programme	○	○	○	○	○
Better resources (videos, apps, printed material webinars, courses) would encourage me to complete an injury prevention exercise programme	○	○	○	○	○
More training in delivery of the programme would encourage me to complete an injury prevention exercise programme	○	○	○	○	○
The introduction of a ball or skills training into the programme would encourage me to complete an injury prevention exercise programme	○	○	○	○	○
A player in your team having a serious injury during a game or training would encourage me to complete an injury prevention exercise programme	○	○	○	○	○
I would be willing to perform an injury prevention exercise programme if data proved I would run faster	○	○	○	○	○

I would be willing to perform an injury prevention exercise programme if data proved I would jump higher	○	○	○	○	○
I would be willing to perform an injury prevention exercise programme if data proved I would have fewer injury risk factors when I move	○	○	○	○	○
I would feel comfortable leading my team in an injury prevention exercise programme	○	○	○	○	○
I would feel comfortable with a teammate leading my team in an injury prevention exercise programme	○	○	○	○	○
I would feel comfortable with my coach leading my team in an injury prevention exercise programme	○	○	○	○	○
I would feel comfortable with my athletic development coach (fitness/S&C coach) leading my team in an injury prevention exercise programme	○	○	○	○	○
I would feel comfortable with my athletic therapist/physiotherapist leading my team in an injury prevention exercise programme	○	○	○	○	○

Display This Question:
If Do you identify primarily as a Gaelic games coach or player? = Coach
Q40 The following questions are related to your ability to conduct an injury prevention exercise programme. Please select one answer that best fits your opinion (Extremely confident, Confident, Neither confident nor not confident, Not confident, Extremely not confident)?

	Extremely not confident	Not confident	Neither confident nor not confident	Confident	Extremely confident
How confident are you that you understand injury prevention exercise programmes well enough to use them with your team for the upcoming season?	○	○	○	○	○
How confident are you that you have the ability to use the injury prevention exercise programmes well enough with your team for the upcoming/current season?	○	○	○	○	○
How confident are you that you have the ability to evaluate the performance of the exercise exercises in the injury prevention exercise programmes?	○	○	○	○	○
How confident are you that you have the ability to correct the poor performance of the exercises in the injury prevention exercise programmes?	○	○	○	○	○