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At the heart of South Leinster

**A Study to Evaluate the Effects of a Neuromuscular Injury
Prevention Programme (GAA15) in
Adolescent Males Participating in Hurling.**

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Abstract

Introduction: Adolescent involvement in organised sport has never been more popular in Ireland, however, this increased level of activity has reportedly caused concern regarding the potential risk and severity of sporting injuries (Lunn et al. 2013). Previous research into adolescent injury incidence in a variety of multidirectional sports, including rugby, soccer, and basketball have established a decline in injury rates following the implementation of injury prevention programmes (Ekegren et al., 2015). Former investigations into injury incidences and rates within the Gaelic Athletic Association (GAA) has primarily focused on elite adult players. However, a recent investigation into the epidemiology of injury in male adolescents, O' Connor et al. (2016) discovered that 35.6% of this cohort were at risk of injury with 27.9% of injured participants at risk of sustaining a subsequent injury in that same year. Adolescents in sport are at risk of injury secondary to potential training overload on an immature skeletal system (Kang et al., 2013). The aims of the current investigation are to assess and critically analyse the application and implementation of a neuromuscular injury prevention programme (GAA15), evaluate injury rates and compare the effects of the programme on neuromuscular performance tests in adolescent boys participating in hurling.

Methods: A sample of 821 male subjects, between the ages of 13 and 18.5 years, were recruited from fourteen post primary schools and six GAA clubs. Schools and clubs were invited and selected based on geographical practicality and then allocated to either an intervention or control group. Seven schools and three clubs participated in the intervention group with equal group numbers in the control group. The intervention group implemented an injury prevention programme namely the GAA15 before training and matches. The control group adopted their normal warm-up behaviour prior to matches and training.

Results: The GAA15 exhibited a positive improvement between the two groups with an overall reduction in lower extremity injury rates ($p=0.063$), however not statistically significant, from a practical viewpoint, it should encourage coaches to use the GAA15 injury prevention programme. School control group participants sustained lower extremity training injury rates (IRs) of 15.83/1000hrs (95% CI 9.4-22.3) compared to 8.78/1000hrs (95% CI 5.2-12.4) in the intervention group ($p=0.063$, z). Club control players experienced training IRs of 15.29/1000hrs (95% CI 3.1-27.5) compared to 13.56/1000hrs (95% CI 7.5-19.7) for the intervention group ($p=0.271$). Match lower extremity IRs of 36.32/1000hrs (95% CI 21.1-51.5) and 35.74/1000hrs (95% CI 11.0-60.5) were reported for the school and club control groups respectively, with 25.62/1000hrs (95% CI 16.9-34.4) and 35.11/1000hrs (95% CI 21.9-48.4) reported for the intervention group participants ($p=0.230$ and $p=0.960$). Lower extremity injuries made up 66.5% of all injuries recorded with the knee being the most frequently injured body part. Performance test results displayed significant improvements within the groups from pre to post-testing; school and club intervention groups for the CMJ ($p<0.001$) and club intervention group for the 20m sprint ($p<0.001$).

Conclusion: Schools hurling training and match lower extremity IRs were reduced by 45% and 30% respectively in the intervention group when compared to the respective control groups, with club IR reductions of 11% and 2% being recorded between the intervention and control groups. Following this investigation, it can be concluded that the implementation of the GAA15 is effective in reducing lower extremity injury rates in adolescent males participating in hurling.

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List of Abbreviations

| | |
|--------------|---|
| ACL | Anterior Cruciate Ligament |
| AFL | Australian Football League |
| BMI | Body Mass Index |
| CI | Confidence Interval |
| CMJ | Counter Movement Jump |
| FIFA | Fédération Internationale de Football Association |
| GAA | Gaelic Athletic Association |
| ICC | Intraclass Correlation Coefficient |
| IP | Incidence Proportion |
| IPP | Injury Prevention Programme |
| IR | Injury Rate |
| IRR | Injury Rate Ratio |
| PAFIX | Preventing Australian Football Injuries with Exercise |
| PEP | Prevent injury, Enhance Performance |
| RPE | Rate of Perceived Exertion |
| SMS | Short Messaging Service |
| TRIPP | Translating Research into Injury Prevention Practice |
| TU | Training Unit |
| WHO | World Health Organisation |

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Chapter 1: Introduction

1.1. Introduction

Adolescent participation in organised sport has never been more popular, however, this increased level of activity raises concern over the risk and severity of injuries. The majority of injuries adolescents receive during sport are not severe enough to necessitate hospitalisation, however, they may require medical treatment, resulting in rehabilitation costs and a potential impediment to future sports participation (Abernethy & Bleakley, 2007). It is accepted that health and well-being can be improved by regular physical activity in adolescence as well as helping to reduce many chronic diseases (Lunn et al. 2013). Previous research into injury incidence in a variety of sports, including rugby, soccer, and basketball have established a decline in injuries following the implementation of injury prevention programmes (Ekegren et al., 2015). According to Bleakley et al. (2011), reducing injury incidence is best accomplished by implementing specific injury prevention programmes (IPPs). The design of such programmes has, historically been based on epidemiological studies, specific to the sport, which demonstrate the injury incidence and risk (Bleakley et al. 2011). Previous investigations evaluating injury incidences and rates within the Gaelic Athletic Association (GAA) has primarily focused on elite adult players. However, following a recent investigation into the epidemiology of injury in male post primary school adolescents, O' Connor et al. (2016) discovered that 35.6% of this cohort were at risk of injury with 27.9% of injured participants at risk of sustaining another injury in that same school year. Although there seems to be good progress at adult level within the GAA, there is a gap at adolescent level (13 – 18 years).

The game of hurling is similar to other sports like field hockey and shinty where players use hand held instruments to strike a ball. A distinguishing feature of this high intensity, physical contact game is the player's ability to run at maximum speed while using sticks to control or hit a ball, which sometimes can reach speeds up to 160 km/h (Murphy et al. 2012). Even though the GAA15 injury prevention programme has been in existence since 2011, it is unclear if it is widely used by adolescent GAA teams around Ireland. Previous literature has found that neuromuscular training programmes can reduce the risk of lower limb injuries along with improving movement and balance techniques

(Herman et al. 2012; O'Malley et al. 2016). Recently one investigation established that by performing the GAA15 injury prevention programme for an 8-week intervention period, it had a positive effect on neuromuscular control in jumping and landing along with dynamic balance improvements in male collegiate GAA players (O'Malley et al. 2016).

Neuromuscular injury prevention programmes have become increasingly popular over the last number of years. Evidence suggests that these programmes can be effective in decreasing injury risk, if they delivered correctly, and are completed regularly (Fortington et al., 2014). Two particular programmes are the FIFA11 and the GAA15, both of which were designed and developed to address the growing injury problem in their respective sports of soccer and Gaelic games. The FIFA11 was created in 2006, in cooperation with the Santa Monica Medicine Foundation, and the Oslo Sports Trauma and Research Centre as a sport specific warm-up to prevent injuries in amateur soccer players (Bizzini & Dvorak, 2015). Similar to the FIFA11, the GAA's Medical, Scientific and Welfare Committee developed the GAA15 injury prevention programme in 2011 using best practice from international research groups. Currently, only one investigation is available into the epidemiological data of adolescent (under 16 years) hurling players (O' Connor et al., 2015).

Regrettably, sporting injuries to adolescents can result in temporary or even permanent reduction of physical activity levels hence contradicting the possible benefits of sport participation (Caine et al., 2014). While it may be impossible to eradicate injuries during adolescent sport, attempts to decrease incidence are evidently justified. Within adolescent sport, poor movement mechanics, unnecessary exercise repetitions, unequal age groups, maturity and experience have all been reported as potential risk factors (Grady & Goodman 2010; Caine & Goodwin 2015). Other potential risks for this age group include previous history of injury, training overload, poor flexibility, balance and functional strength (Theisen et al., 2013).

In the current study, each subject will take part in a neuromuscular performance assessment at the beginning of the research and again at the end, to discover if any physical effects have transpired. These performance tests will consist of; running speed, power, balance, flexibility and strength (see methodology). Each of these performance measures will imitate the neuromuscular attributes required for the game of hurling as

well as being components of the GAA15. Results will be critically evaluated to establish if there is a relationship between the intervention programme and the neuromuscular performance post-trial retest. These performance effects may contribute to a clearer understanding of the mechanisms involved in a successful injury prevention programme to potentially lower injury risk and enhance neuromuscular performance. Motivation of players and coaches to comply with an injury prevention programme would be easier if there was a proven performance benefit (Steffen et al., 2013). Player self-reporting of wellness, activity exposure, and injury incidence will be documented through a mobile phone web application on a daily basis. This electronic questionnaire will enable the researcher to track and monitor the daily activity levels of players and log all incidences of injury throughout their hurling season.

While injury prevention research and strategies are progressing at adult level within the GAA, there is a lack of similar strategies at adolescent level. Previous research is compelling and underlines the necessity to reduce the incidence of injury in this adolescent cohort. Adolescents are at risk in terms of overload and growth related injuries in sport, and the GAA is no exception to this (Caine et al. 2014). The purpose of this research is to evaluate the effects of the GAA15 on this adolescent cohort participating in school and club hurling.

1.2. Aims and Objective of Study

- To evaluate the effectiveness of the GAA15 neuromuscular injury prevention programme in reducing lower limb injuries in adolescent males participating in hurling.
- To compare neuromuscular performance assessment results, pre to post season, within each of the intervention and control groups.
- Establish injury epidemiology data via a self-reporting mobile phone web application.

1.3. Hypothesis

- Implementation of the GAA15 neuromuscular injury prevention programme will decrease injury incidence in adolescent males participating in hurling.
- Neuromuscular intervention strategies (GAA15) will positively affect neuromuscular performance measures from baseline to end of season scores.

Chapter 2: Literature Review

2.1. Introduction

Gaelic games in Ireland consist of hurling, Gaelic football, handball (court), camogie (female version of hurling) and road bowls. At present, Gaelic football, hurling and camogie are the most popular of these sports. Within each of the 32 counties throughout Ireland, competitions are contested between GAA clubs at adult senior, intermediate and junior grades. National and club competitions are also played, involving under 18 (minor) and under 21-year-old grades, with additional local (within each County) juvenile competitions organised for various adolescent teams. At adult national level, the Sam Maguire and Liam McCarthy cups are awarded annually to the county team that wins the All-Ireland Gaelic football and hurling championships respectively.

Despite the modern-day popularity and spectator appeal of Gaelic games, research investigations in the areas of physiology, performance, psychology, injury epidemiology and prevention have lagged noticeably behind other field sports. Therefore, coaches and trainers involved in Gaelic games have a tendency to rely on study outcomes in related team sports, for example rugby, soccer and Australian rules football (Reilly & Collins 2008).

Adolescent post primary school senior (under 18.5 years) hurling is split into two competitions, the league, which runs during a two-month period (October – November) and the championship, which starts in January and finishes with the All-Ireland final in March. Teams potentially have five games during the league (minimum of 3 games) and seven during the championship depending on how successful they are (see **Figure 1**) with the championship being run on a knockout basis. Juvenile (under 14.5 years) post primary school hurling is also structured on a league and championship competition with teams having a minimum of six games (February – April) and a maximum of ten games if they reach their respective finals.

Similar to the post primary school hurling competition, adolescent (under 18 years) club hurling has two competitions, a league and championship. Teams at under 14, 16 and 18 years can expect to play between 10 and 14 games per season, with the league games starting in April and championship games finishing in November (see **Figure 1**).

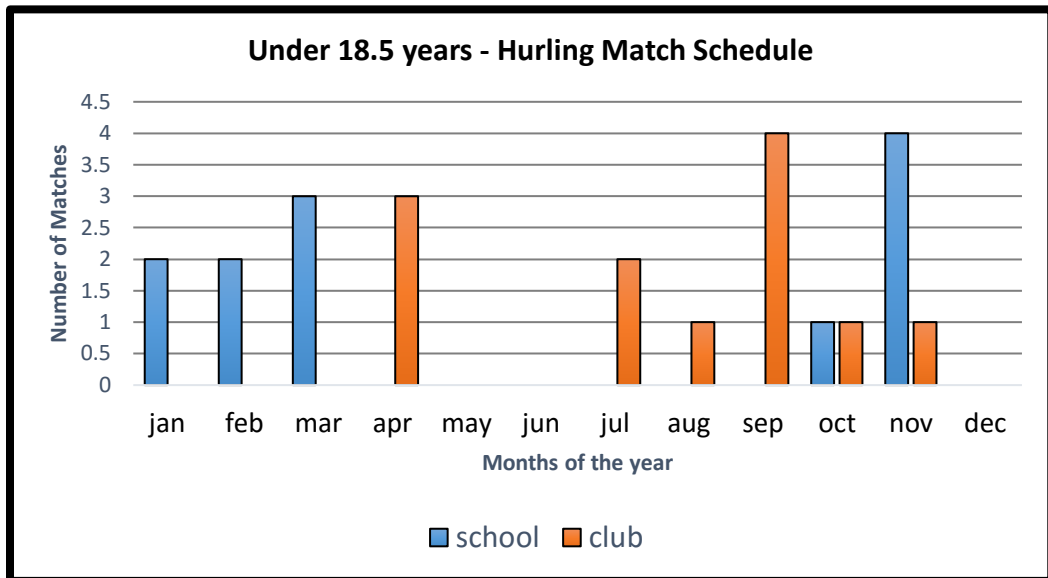


Figure 1: Hurling match schedule for a typical under 18.5-year-old participant

Figure 1 displays a potential competitive match schedule for a typical under 18.5-year-old hurling player, however, this schedule does not take into account other practice and challenge matches they may play with their schools or clubs throughout the year. Even though this is a possible match schedule, it might not be the only competitive matches this cohort take part in, as some players may be involved with multiple teams.

2.1.1. The Game of Hurling

Hurling is a field game involving two teams with fifteen male players on each team played with broad, flat wooden sticks (camán, 890-940mm length of adult camán) and a small leather ball (sliotar) (see **Figure 2**). Each hurling team consists of fifteen players, which include a stationary goalkeeper, six defenders, two mid-fielders and six forwards. At senior (adult) inter-county level, games are played for a total of 70 minutes consisting of two halves of 35 minutes each with a 15 minute break (half-time) period between the two halves. At youth and adolescent level (under 14 – 21 years), games last for 60 minutes, consisting of two halves of 30 minutes each.

The game is played on a grass field with a set of goalposts at either end similar to rugby with a net behind the lower section being the only difference. The playing field for

hurling is rectangular in shape with dimensions ranging from 130-145metres in length and 80-90metres in width. The goalposts consist of two uprights 6.5metres apart and at least 7metres high, with a crossbar 2.5metres above the ground fixed between the posts (GAA 2012) While playing the game, each player has control of a camán and wears head protection (helmet), this is compulsory. The camán is made from the ash tree and during the game is used to strike a small leather sliotar, similar in size to a cricket ball.



Figure 2: Camán and Sliotar

The object of the game is for each team to use the camán to score by putting the sliotar over the crossbar, to score one point, or a team can also strike the sliotar below the crossbar and into the net to score a goal (three points). The sliotar can be propelled large distances, anything up to 100metres, through the swinging action of the player with the camán (Dolan & Connolly 2009). During the game, players from the opposing teams challenge for possession of the sliotar with frequent high intensity periods of activity. Physical contact between players is allowed by tackling shoulder to shoulder but pushing or tripping an opponent is against the rules of the game. A player in possession of the sliotar is permitted to run four steps before passing or striking it, and can only catch it twice in their hand before releasing or striking for a score. To gain possession, the sliotar must be lifted from the ground using the camán and it is against the rules to pick it up with the hand (GAA 2012).

2.1.2. The GAA in Numbers (2014-2016)

Gaelic games are high intensity contact sports that have a high injury risk during training and matches (O' Connor et al. 2015). Depending on the age and level of competition, participants are playing the game more physically than in the past, necessitating higher levels of physical fitness and more demanding training programmes (Murphy et al. 2012). Considering the elevated numbers and physical nature of playing Gaelic games, it is no surprise that these factors contribute to a high risk of injury. Currently there are 2,014 affiliated GAA clubs playing Gaelic games throughout the 32 counties of Ireland. This popularity may be largely due to the local communities (parish) being the foundation for the club system. Previously, Irish immigrants to the United States of America, the United Kingdom, and Scotland introduced Gaelic games to these countries. As a result, there are now 315 International GAA clubs affiliated to the organisation. Throughout the 2014 inter-county Gaelic football and hurling championships, 1,541,309 supporters attended games. During 2014, the GAA had a membership of 508,936 which included 334,339 registered players. This consisted of 14,789 youth teams and 3,996 adult teams. Over 200,000 youths aged between 8 and 18 years were members of the GAA in 2014, these included pupils from 3,981 primary schools and 931 post-primary schools throughout Ireland. During the summer holidays from school, the GAA organises children's summer camps, in 2016 127,473 children (5-13 years) attended such camps. The GAA also organises a National competition (Féile) for under 14 years' players, with 14,760 juveniles from 352 teams participating in 2014. Social media also plays a big part in the modern GAA world with 307,000 followers of the GAA Facebook and Twitter platforms, 3,000,000 visits to the official GAA website and 2,400,000 minutes watched on the 'Official GAA' YouTube channel in 2014. In 2016, the GAA launched its official Snapchat account, and during the senior hurling championship final this was viewed by 300,000 people in Ireland and Britain (GAA 2015; GAA 2016).

The GAA could possibly be described as one of the most prosperous and flourishing amateur organisations in world sport and certainly in Irish sport. It could also be defined as the biggest and most important socio-cultural movement in Ireland. Given the ever-increasing popularity of Gaelic games participation, it is imperative to establish the risks of injury, identify epidemiological data and then look at ways to try and decrease injury

incidence and the risks associated with injury. To improve injury prevention within their sport, the Australian Football League (AFL) decided it was crucial to demonstrate that the implementation of any injury prevention strategy needed to accomplish its desired objectives i.e. enhanced compliance and reduced injury rates (Finch et al. 2009). Therefore, it is imperative that appropriate and accurate research is carried out in Gaelic games to encourage the widespread use of injury prevention strategies.

2.2. Adolescence and Physical Activity

Adolescent's involvement in organised sport has never been more popular in Ireland with almost 90% of primary school students participating in either organised sport or playing sport recreationally with friends (Lunn et al. 2013). Sport participation rates in the United States has also increased considerably over time with approximately 18 million children engaging in sport in 1987 to 60 million in 2008 (Ferguson & Stern 2014). Adolescents participating in regular physical activity during childhood improve overall health and wellbeing and may reduce the risk for many chronic diseases (Caine et al. 2014). The World Health Organisation (WHO) recommends that children aged 5-17 years old, participate in physical activities that include playing games, recreation, and planned exercise, in the context of family, school and community activities. To improve cardiorespiratory, muscular fitness, bone health and metabolic health, the WHO suggests children should accumulate at least 60 minutes of moderate-to-vigorous intensity physical activity daily. It also suggests the inclusion of exercises that strengthen muscle and bone, at least 3 times per week (Bergeron et al. 2015; World Health Organization 2015).

In adolescent sport competition, players are divided into groups and teams according to their chronological age. The GAA has an age cut-off point of December 31st for all juvenile and youth team competitions. The purpose of this cut-off point is to ensure equal opportunity and development of the players and that all competitions are fair and present the same chances of success for those who participate. However, with most GAA team competitions consisting of 2-year age grades (under 14, 16 and 18 years), this age separation can regularly display differences in cognitive, emotional and physicality

between the oldest and youngest child within the same playing age group (Musch, 2001). Adolescents born close to the January 1st start date are the oldest while those born far away from this date are the youngest ones. Because of this relative age effect, it is possible to have players competing against each other with almost 24 months between the youngest and oldest, which has the potential to cause major differences in performance (Barnsley et al. 1992). It can also have sizable anthropometric variations with differences in development and growth rates between those born at the beginning of the year versus those born later in the year (Helsen et al. 2005). As a consequence of the 24-month age differences in players, there may be concern about the safety and increasing prevalence of sport injuries in the younger participants. Physical size, strength, speed and coordination are highly correlated with age (Caine & Goodwin 2015), therefore older players within an age group possibly will demonstrate improved performance and accordingly, physical maturity maybe mistaken for ability, by team coaches, trainers and players. These age-advantaged players may develop greater self-confidence with the opposite effect happening in the younger players (van den Honert 2012).

A recent study by Stracciolini et al. (2016) investigated the relationship between relative age effect and sports injury, where relative age was defined as the subject's month of birth relative to the age cutoff for their particular sport. Statistics were extracted from a regional hospital database in a sample of 1,997 children between the ages of 5 and 17 with sports injuries (Stracciolini et al. 2016). This relative age effect was classified as children born after a calendar cut-off month as possibly having an advantage in both school and sport due to their emotional and physical development relative to their colleagues. In the 5 to 13-year age group, results revealed that the children furthest away from the cutoff point displayed a higher risk of injury compared to those closer to the cutoff. It also revealed that for every subject with an injury, there was a slightly lower rate of injury for each month after the cutoff point. However, the opposite was the case with the 14 to 17-year-old group, with more injured subjects born during or slightly after the cutoff compared to those born furthest away from the cutoff point. A similar investigation in Canadian youth ice hockey established that older children within age groups were at an increased risk of injury when compared to their younger teammates (Wattie et al. 2007). It was also discovered in the same study that older players were at

a greater risk of injury, the more competitive the level they were playing at. It was suggested that the older children were more likely to be selected for teams and as a result were more likely to get injured, therefore the advantage of team selection carried the disadvantage of increased playing exposure and greater risk of injury.

Prior investigations have suggested that adolescent height, weight, muscular strength, aerobic power, endurance and speed, ensure an advantage in most sports (Cobley et al. 2009). In addition, it is generally believed that older adolescents maybe at greater risk of injury because they are more skeletally mature, heavier, faster, stronger and produce more force in contact sport situations (Emery et al. 2005; Caine et al. 2008). Likewise, a one-year age difference in sporting competitions where chronological age groups are in use, can amplify physical and performance differences. Within the GAA age grading system it can be postulated that having a two-year gap can only further magnify this issue.

2.2.1. Anthropometric Considerations

It has been suggested that people with different physiques can exhibit distinctive performance capabilities during physical exercise and that a person's body composition, together with anthropometry measurements can have a positive effect on cardiorespiratory and cardiovascular responses during exercise (Bolonchuk et al. 2000). Equally, previous studies show a higher occurrence of injuries among taller, heavier adolescents, possibly due to greater forces being absorbed by soft tissue and joints in this cohort (Caine et al. (2008). It was further reported by Vanderlei et al. (2014) that mean values for height, weight, and training exposure times were greater in adolescents with a previous history of injury. Understanding the multiple risk factors that place adolescents at risk while playing sport needs to be an essential part of any injury prevention investigation. Anthropometric factors and a history of previous injury have previously been established as non-modifiable injury risk factors in sport injury literature (Emery 2003).

Age

As previously mentioned in section 2.2, older adolescents could potentially be at a greater risk of injury because they are physically more mature and are likely to produce more force during contact sport (Emery et al. 2005; Caine et al. 2008). However, the relationship between adolescent age, gender, competition level and rates of injury seems to be more sport specific. For example, previous adolescent sport injury investigations in rugby (Bleakley et al. 2011), soccer (Emery et al. 2005) and American football (Malina et al. 2006) have reported that the incidence of injury has increased with the age level in male adolescents. In contrast, hockey (Emery & Meeuwisse 2006), and female soccer (Emery et al. 2005), both report significantly higher rates of injury in the younger age group compared to the older group. The ever increasing popularity of adolescent involvement in organised team sport is well known, however, the participation in sport from an early age raises concerns about injury risk and severity.

Body Composition

There is a scarcity of research into adolescent body composition as an independent modifiable risk factor for sport injury (Richmond et al. 2013). However, one investigation which examined body mass index (BMI) and injury, reported that adolescents with a higher BMI (18.5 – 24.9) had higher injury rates when compared to those of a healthy weight (<18.5) (Rose et al. 2008). Body mass index (BMI) is a noninvasive simple measure of a person's body fat composition based on their weight in relation to height. This study (Rose et al. 2008) arranged the BMI data into percentiles and was not based on the subjects age and gender. Furthermore, it was noted that because of the self-reporting nature of this study, adolescents in the age group (12 to 19 years) systematically underreported weight, especially those that were overweight. This investigation concluded that higher levels of BMI were associated with poor levels of fitness including inadequate strength, neuromuscular control, balance and coordination, which most likely placed these adolescents at a greater risk of injury. In the same way, Richmond et al. (2013) reported that adolescents with a high BMI were at an increased risk of obtaining a more severe injury, resulting in a longer period of time absent from play (more than seven days). Similar to the Rose et al. (2008) study, this investigation failed to measure the fitness levels of participants together with mechanisms and type of

injury which could be limitations. Interestingly, this author recommended that sport injury prevention programmes should include educational information and guidelines to be directed at both healthy body weight and injury prevention.

A similar study by Ezzat et al. (2014) also examined the relationship between overweight and normal weight adolescents and the risk of sport injury. Results showed that in a sample of 6,163 adolescents (12 to 19 years), 25% reported receiving an injury from sport during the previous 12 months. However, no significant relationship was discovered from adolescents being overweight and sport injury (1.05, 95% CI 0.90–1.22). This study concluded that overweight active adolescents did not appear to be at any increase risk of injury when compared to normal weight adolescents.

The contradictory results established from these investigations could possibly be due to inconsistent self-reporting weight measurements together with improper grouping of healthy and overweight adolescents along with unsure normative values. Adolescent's interest and participation in a variety of sports from an early age has never been more common, however, this increasing participation rate is set against a backdrop of unique physical characteristics which can lead to vulnerability of injury (Caine et al. 2014).

2.3. Epidemiology of Injury in Sport

Adolescent participation in sport has never been more popular and provides various health, wellbeing and social benefits, however this increased level of activity has reportedly caused concern regarding the potential risk and severity of sporting injuries (Warburton et al. 2006). Previous research into adolescent injury incidence in a variety of multidirectional field sports, including rugby, soccer and Australian Rules football have established a decline in injury rates following the implementation of injury prevention programmes (Ekegren et al. 2014).

It is acknowledged that a standardised injury definition is fundamental to reproduce reliable data that is available for comparison within and across sporting disciplines worldwide. This standardisation provides a base from which epidemiological studies can be contrasted and compared, with the ultimate aim of influencing injury prevention management. In line with prior research has recommended various definitions of injury

and the researcher was cognisant of these when reviewing the literature and conveying the outcomes in section 2.3.1. In line with prior epidemiological literature, the current investigation has defined injury as, “any injury sustained during practice or competition resulting in time lost from play or an athlete reported performance restriction” (Brooks 2005; Murphy et al. 2012; O’ Connor et al. 2016). There are two types of epidemiological research, analytic and descriptive. Analytic epidemiological research describes how and why injuries occur and also identifies strategies to control and prevent them happening. Quantifying the amount of injuries per athlete along with when and where the injury occurred and time lost from play is represented by descriptive epidemiology (Caine et al. 2008). The first steps needed to prevent injury in any sport is to establish the injury incidence and severity in a particular sport along with the aetiology and mechanism of injury (van Mechelen 1997). Former investigations into injury incidences and rates within the GAA has primarily focused on elite adult players. However, following a recent investigation into the epidemiology of injury in male post primary school adolescents, O’ Connor et al. (2015) discovered that 35.6% of this cohort were at risk of injury with 27.9% of injured participants sustaining a subsequent injury in the same school year. Investigations in other sports have suggested the transition between school years could potentially increase the athletes susceptibility to injury. It would be expected that activity levels and training load would be significantly higher in post primary when compared to primary school level (Wolf et al. 2009).

2.3.1. Incidence of Injury

The National Research Council in the United States has recognised sporting injuries as a significant public health crisis with medical costs estimated to be more than US\$280 million annually. They have also identified non-competitive recreational sport injury as an area which requires further research (Weaver et al. 2002). A typical aim of any sports injury investigation is to highlight the potential risk factors affecting participants and assess and investigate the injury prevention strategies that are in existence. In sport injury literature, incidence of injury refers to the numbers of injuries (incidences) divided by the total number of subjects at risk and multiplied by a time value and

reported as incidence rate (IR) (Caine et al. 2008). Incidence proportion (IP), however measures the average risk of injury which is established by dividing the number of injured participants by the total number of participants at risk during a definite period of time (Knowles et al. 2006). The International Olympic Committee (IOC) reports that athletes involved in youth sports and aged between 11 and 18 years have been reported to have an estimated injury IP of 35 injuries for every 100 youths, who annually require medical attention (Bergeron et al. 2015). The IOC describes the lower extremity as the most frequently injured part of the body with more than 60% of the overall injury burden. This is in keeping with findings of O' Connor et al. (2015) who found that 58% of injuries in adolescent hurling players were to the lower limb. Internationally it is reported that, Ice hockey (IR range: 5 to 34.4), rugby (3.4 to 13.3), basketball (3.6 to 4.1), soccer (2.3 to 7.9) and American football (3.4 to 16.2) have the highest sport specific injury IRs per 1000 hours of exposure (Caine et al. 2008; Bergeron et al. 2015).

Following a 10 year investigation into a variety of sports where patients were treated for injuries at a sports clinic, it was reported that lower limb injuries accounted for 68.7% of all injuries presented (Habelt et al. 2011). During this investigation 19,530 injuries from 17,397 patients were analysed and it was reported that 4,468 injuries (25.7%) were from subjects between the ages of 10 and 19 years with almost 67% to males. Each incidence was classified into gender, injury type, part of the body and what sport the injury occurred in, as well as treatment administered. Every injured subject was examined by, or was under the supervision of, a senior consultant during an outpatient sports clinic. All injured subjects were examined clinically for pain, swelling, range of motion and stability following a radiographic evaluation. In the same study, upper body injuries accounted for 25.27% of all injuries reported with 2.57% to the spine and 1.99% to the head region. The most frequently injured lower body part was the knee (29.79%) followed by the ankle joint (24.02%).

A systematic review of adolescent rugby union injury epidemiology reported that injuries needing medical attention varied, from 27.5 to 129.8 injuries per 1000 match playing hours (Bleakley et al. 2011). Upper extremity fractures, dislocations and knee ligament injuries were the most frequent sites of injury that required time out from the game. A further investigation examining the epidemiology of injuries in schoolboy rugby union players compared to senior club players, reported that 154 schoolboy players

experienced 210 injuries, with 80% of these taking place in matches giving an IR of 86.8. However, this particular study reported injuries per 1000 players per season and not hours of participation which is a limitation that restricts comparison to other studies (Lee & Garraway 1996).

A previously reported investigation in a sample of 21 adolescent soccer teams (aged 12 to 18 years) discovered the overall IR was 5.59 injuries per 1000 playing hours (Emery et al. 2005). Direct player-to-player contact was reported to be involved in 46.2% of injuries with ankle and knee injuries being the most common injuries registered, with 78.2% of all injuries to the lower extremity. The risk of injury was found to be 2.5 times greater in matches compared to training in boys (12 to 18 years) with an 8-fold increase in the 16 to 18-year-old age group.

Similar differences were reported in male adolescent hurling, with players 3.69 times more likely to pick up an injury during a match compared to training (O' Connor et al. 2015). Likewise, at elite adult hurling level, more injuries occurred in matches (56.9% of all injuries) compared to training (35.1%) with a risk of match injury 20.7 times that for training injury (Blake et al. 2014). These outcomes are consistent with an observational study of Irish collegiate rugby and soccer players that reported rugby injury rates of 99.5 per match activity and 5.1 for training (19.5 times higher risk). In the same study, soccer match injuries resulted in 49.3 injuries with 7.1 training injuries per 1000 playing hours being reported (6.94 times higher risk) (Farnan et al. 2013). However, this observational study only lasted three months and focused on collegiate players aged 21 years and over.

The majority of injuries (45.2%) recorded during a study into the 2015 youth lacrosse season were to the lower extremity, these comprised of contusions (51.6%) and sprains (14.8%) (Kerr et al. 2016). This investigation displayed an overall rate of 12.98 injuries per 1000 hours of athlete exposure with 60% of all injuries occurring during matches. A large amount of these lacrosse injuries were caused by equipment-to-player contact (35.5%), ball-to-player contact (14.2%), and player-to-player contact (18.1%). Similar to hockey, lacrosse can be compared to hurling with players using sticks to hit a ball while playing the game.

Previous research into adolescent sport has supported the theory that there is a high frequency of injuries, with up to a third of adolescent hurling players receiving an injury

and over a quarter of these players sustaining a subsequent injury throughout a season (O' Connor et al. 2015). This informs us that, potentially, for every team of fifteen players, five of those players will pick up an injury in any one competitive season. Another, more serious issue for GAA teams is, what if these five players get injured at the same time and maybe before an important championship match, this potentially would have repercussions for team performance and match results. This in turn can lead to extra pressure being placed on the other players to perform, potentially resulting in psychological stress for the team coach, trainer, players and their families. At senior (adult) elite hurling level, this rate of injury is higher with an IR of 1.2 injuries per registered player recorded during a five-year prospective cohort study, and with team panels of 30 players, potentially 22 players could get injured during a season (Blake et al. 2014).

Adolescent hurling match injuries are also more frequent than training injuries and this is despite players spending 6.5 times more time in training (O' Connor et al. 2016). This rate of injury is even higher at elite adult hurling level with players 20.7 times more likely to receive an injury during a match compared to training (Blake et al. 2014). Injury incidences in other adolescent sports like basketball (1.94/1000, injuries per hours of athlete exposure), and soccer (2.4/1000hrs) both show lower rates of injury when compared to hurling (4.39/1000hrs) (Bleakley et al. 2011; O' Connor et al. 2015). This difference in injury rates may be attributed to the higher intensity, physicality and competitive nature of hurling match play, along with the use of a sporting instrument (camán) (Theisen et al. 2013).

Having reported the high frequency of lower limb injuries in adolescent hurling, O' Connor et al. (2016) recorded lower back (22%), knee (20%), ankle (10%), pelvis and groin (10%) as the most frequently injured sites. In the same investigation, high incidences of injury to the trunk and spine area was also documented. This maybe as a result of the rotational nature of the game of hurling which involves striking the ball while rotating the body (O' Connor et al. 2015). It has previously been reported that injuries take place when energy is transferred to a body region, in amounts or rates that go beyond the maximum for human tissue damage (Meeuwisse et al. 2007).

Injuries are prevalent in adolescent sports with lower extremity injuries, mainly knee, hamstring, and ankle the most frequent. The current investigation is looking at the

effectiveness of an injury prevention programme in reducing injuries in adolescent males who play hurling. It is imperative that national governing bodies such as the GAA are equipped with the evidence on the effectiveness of injury prevention strategies such as the GAA15 in helping decrease injuries in adolescents.

2.4. Injury Risk Factors

Injury risk factors in sport can be classified as any factor/s that potentially intensify the risk of injury to participants of that sport (Caine et al. 2014). Participation in sport harbours the risk of injury as previously outlined in section 2.3.1 and this results in unprecedented numbers of injuries each year which can manifest in time lost from play together with high medical costs and other potential health consequences. There are numerous factors that may cause an athlete to be injured, with both extrinsic (items external to the body such as training methods or equipment) and intrinsic (individual biological and psychosocial influences, including previous injury and life stress) being suggested (see **Figure 3**). Sport injury risk factors can be further divided into modifiable and non-modifiable factors. Modifiable risk factors are those that can be potentially changed by injury prevention strategies. Non-modifiable risk factors, such as age, and gender and previous history of injury cannot be adjusted and may affect the connection between modifiable risk and injury (Caine et al. 2008).

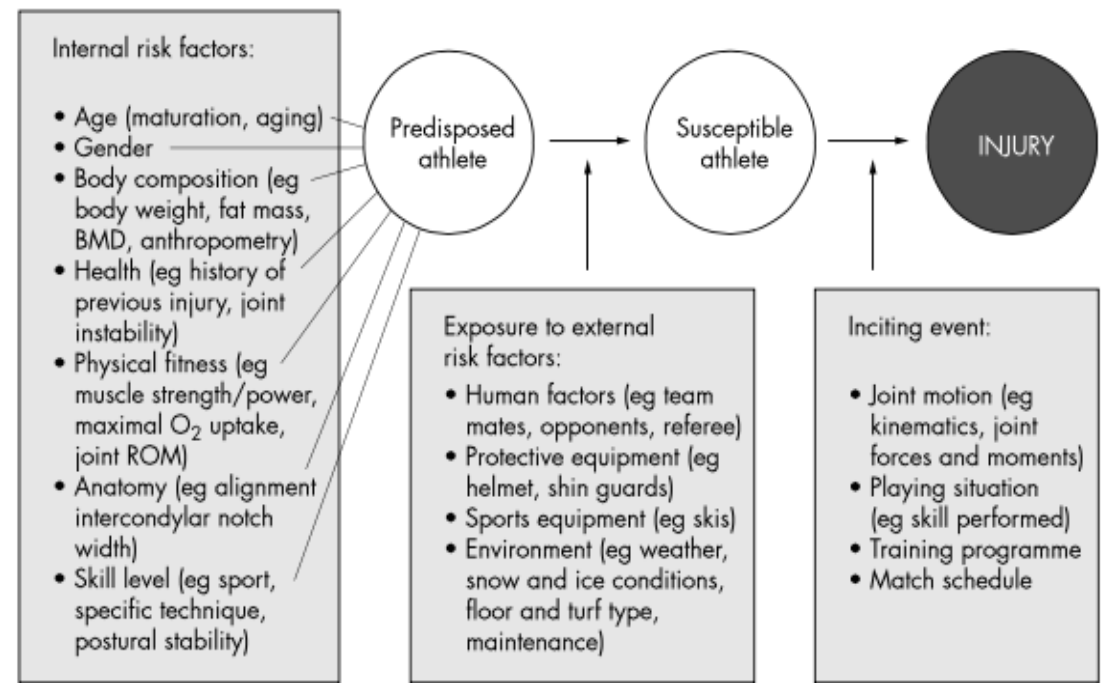


Figure 3: A Dynamic, multifactorial model of sports injury aetiology. (adapted from Bahr & Holme, (2003).

2.4.1. Intrinsic Risk Factors

Gender

It remains unclear whether the risk of injury in sport is due to sports specific gender distinction or associated with biological gender differences (Ristolainen et al. 2009). One researcher that investigated gender differences looked solely at injuries to a particular body part e.g. knee injuries (Agel et al. 2005). This investigation reviewed all data relating to anterior cruciate ligament (ACL) injuries in male and female participants in both basketball and soccer from 1990 to 2002. In total, 1,268 ACL injuries were reported following this 13-year investigation in 6,176 schools. In conclusion, Agel et al. (2005) established the rate of ACL injuries in females to be significantly higher than males regardless of injury mechanisms in both basketball and soccer. However, a further investigation suggested, there is only minor differences in patterns of injury between male and female participating in comparable sports (Sallis et al. 2001). This retrospective cohort study compared the pattern of injuries between male and female athletes from seven different sports over a 15-year period to see if any specific risk factors existed and

if it was possible to modify these to reduce the risk of injury. In general, there were no significant gender differences for risk of injuries observed, with only two sports showing a variance, swimming and water polo. It is possible that other factors may have contributed to different rates of injury in male and female athletes, for example, in one study (Wolf et al. 2009), established an enhanced rate of shoulder injuries in female swimmers may have resulted from a more rigorous training programme by their coach.

Maturation and physiological development

There is a scarcity of research into adolescent maturity and the risk of injury in sport, with contrasting results from investigations (Le Gall et al. 2007). One prospective study evaluated injuries in soccer and their relationship to adolescent physical maturity in youths aged between 6 and 17 years (Backous et al. 1988). Injury incidence increased with age; this was attributed to games getting faster and more physical as the participants got older, with a noticeable increase from 14 years onwards. Likewise, a similar study in American football established a correlation with increased injury rates and advanced maturity in 340 junior high school athletes aged between 11 and 15 years. Linder et al. (1995) prospectively observed these athletes for two consecutive seasons with stages of maturation being determined by a physical examination before the start of each season. In conclusion, it was established that athletes who experienced sexual maturation could potentially be at a greater risk of injury while playing contact sports. However, in contrast to these studies, Baxter-Jones et al. (1993) investigated a group of 453 elite young athletes between the ages of 8 and 16 across four sports in order to identify self-reported injury incidences. Injuries were tracked over a two year period, with the highest risk of injury in soccer (67%) and the lowest in swimming (37%). This investigation established no significant associations between injury rates, the severity of injury, gender, and maturity status of the athletes, with one exception, in female gymnasts encountering more injuries during the latter stages of puberty.

Previous Injury

A history of previous injury is an inherent intrinsic risk factor to subsequent injury. Arnason et al. (2004) investigated the risk factors for football injuries in 306 male

football players and established that age and previous injury (four to sevenfold increased risk) were found to be the most influential risk factors for injury. Similarly, Ekstrand and Gillquist, (1983) established that a minor injury was regularly followed by a more significant injury within two months, and these injuries were of the same type and to the same body location.

Kucera et al. (2005) concurred with these authors reporting an increased risk of injury following a previous injury, however, the risk was smaller with a twofold increase risk in players with one previous injury and a threefold increase in players with two or more previous injuries. This was a prospective cohort study of 1,483 youth soccer players (under 12 to 18 years) of which 59.7% sustained an injury. This investigation concluded that youth soccer players were at a greater risk of injury if they had a previous injury incidence.

There are several hypotheses that could account for reoccurrence including, the player returning to play before completing proper return-to-play protocol, the original injury not healing properly, the player not adhering to correct rehabilitation guidelines.

2.4.2. Extrinsic Risk Factors

Playing Exposure Time

It has been speculated that too much sporting activity (overuse) may predispose the adolescent athlete to an increased risk of injury (Brenner 2007). With organised sport and recreational participation becoming more popular leading to increasing children and adolescents participation, the incidences and rates of overuse injuries is growing (Brenner 2007). Many adolescents are playing organised team and individual sport all-year round often with multiple teams and different sports. The excessive playing demands being placed on young athletes at all levels of sport are constantly being linked with player overuse, burnout and fatigue syndromes (Brenner 2007; Fraser-Thomas et al. 2008). Burnout can be defined as physical and emotional exhaustion, a lowered feeling of achievement which can be revealed by reduced performance or an individual's perception that they are unable to reach definite performance targets which can lead to a reduced participation in their chosen sport (Walker 2013). It has been suggested

that player burnout could be the result of a long-term discrepancy between a players coping resources, physical and social stresses that they are exposed to over a long period of time through training and competition (Walker, 2013).

A recent study on elite adult Gaelic football players investigated the relationship between match and training load and the risk of injury (Malone et al. 2017). The results of this investigation displayed a positive linear association between weekly workload, changes in week-to-week workload and subsequent risk of injury throughout the playing season with the risk increasing as the season progressed. In conclusion, Malone et al., (2017) suggested that match and training loads should be individually monitored for week-to-week changes to help reduce the risk of injury in adult sport, however, this may also apply to adolescents.

Wellness – Sleep

There is a scarcity of information about the role that sleep deprivation plays in the risk of sport injury in adolescent athletes. One investigation reported that adults suffer from weakening psychomotor performance following small periods of sleep loss (Vgontzas et al. 2004), but in spite of this, there is very little known about the effects on children and adolescents. Sleep patterns were examined in a further investigation, along with training practices and the risk of injury in 112 adolescent student athletes (12 – 18 years, 54 males and 58 females) by a self-reporting online survey (Milewski et al. 2014). The online survey information collected from the athletes was correlated with data from school sport injury records. Results from the 112 athletes revealed, 64 athletes (57%) incurred a total of 205 injuries, 42 athletes (38%) experienced more than one injury and 48 athletes (43%) did not receive any injury during the 21-month study period. This study established that athletes who had less than 8 hours' sleep were 1.7 times more likely to have an injury when compared to athletes who had more than 8 hours' sleep. On average the athletes that slept less than 8 hours per night were 1.7 times more likely to receive an injury than those that slept more than 8 hours. However, it is worth nothing that this study only included subjects from a single private school and included males and females. The study didn't report injury IRs, mechanism, type or location of injuries and furthermore it didn't consider whether participants napped during the day, so care needs to be taken when generalizing to other populations.

Wellness - Hydration

An athlete's level of hydration is an important consideration when competing in sport in order to avoid dehydration and support cardiovascular and thermoregulatory functions within the body which are vital to maintain best possible performance (Edwards et al. 2007). Athletes can experience diminished levels of performance as a result of dehydration along with an increase in core body temperature and a reduction in the body's capacity to tolerate heat produced during physical activity which all can have severe implications on the athletes performance and health (Shirreffs & Sawka 2011). It is possible that preventing dehydration in children and adolescents is more important as these young athletes are at a greater risk as they produce superior amounts of metabolic heat compared to adults, due to smaller surface area to body weight ratio along with not being able to generate sweat as capably as adults (Meyer et al. 2007; Gordon et al. 2015). During dehydration, the core body temperature in children rises quicker when compared to adults and also children have an elevated sweating threshold (Meyer et al. 2007). Adult athletes can display deficits in strength, reduced power output, impaired physiological function and poor levels of performance following a 2% to 3% dehydration effect (Edwards et al. 2007).

Gordon et al. (2015) looked at the hydration status of 79 youth soccer players (14 to 17 years) before and after two training sessions, using urine specific gravity and any percentage loss of body weight. Results established that 27% of players were extremely dehydrated after training, with 24% being extremely dehydrated before the training session started. It was also noted that a small percentage were hyperhydrated before (3%) and after (6%) training respectively. The average body weight reduction across the whole group following the two training sessions was 0.4kg. A limitation of this study is that it was carried out with socio-economically disadvantaged male adolescents during training sessions and not matches with fluid consumption habits possibly changing because of the research monitoring. Furthermore, hydration classification status was based on previous research from adult subjects due to the lack of published adolescent data. The American College of Sports Medicine recommends that youth athletes consume between 5 and 7ml of fluid per kg of body weight during the 4 hours before physical exercise, which should be enough fluid to reduce changes in body weight to less

than 2% during the activity (Smith et al. 2015). It also advocates consuming 450 to 675ml of fluid for every 0.5kg of body weight lost during physical exercise.

Training v's Competitive Matches

A number of investigations are in agreement that injury incidence is greater during matches compared to training sessions (Farnan et al. 2013; Blake et al. 2014; O' Connor et al. 2015). While investigating the epidemiology of injury in 856 elite hurling players, Blake et al. (2014) recorded 1,030 injuries with a resultant IR of 1.2 injuries for each player registered. More injuries occurred during competitive matches (56.9%) compared to training (35.1%) sessions in this cohort. Match injury incidence rates resulted in 61.75 injuries per 1000 hours of match play compared to 2.99 injuries per 1000 hours of training exposure.

Similar results were discovered in adolescent hurling players with players sustaining more injuries during matches compared to training, 11.11 and 3.01 per 1000 hours of exposure respectively (O' Connor et al. 2015). In the same investigation, adolescent Gaelic football players displayed comparable results with 9.26 and 2.69 injuries per 1000 hours of exposure.

Soccer also exhibited similar results, with a High school investigation in the United States concluding that injuries were three times more likely to happen during match competition compared to training practice (Yard et al. 2008). This study reported that match injuries were more frequent because of the greater exposure to full contact high risk activities during competitive matches. The injury IRs reported were 4.77 and 1.37 injuries per 1000 hours of exposure time for match and training respectively.

Similarly, playing competitive rugby matches also demonstrated higher incidence rates of injury when compared to training exposure in a 3-month observational study of 54 male collegiate rugby players (Farnan et al. 2013). Match and training exposure (per hour), along with injury status details were collected fortnightly by means of a questionnaire giving a player response rate of 92.7%. Fifty-one injuries were recorded during the 3-month period, giving a match and training IR of 99.5 and 5.1 injuries per 1000 hours of exposure respectively. These similar findings suggest that training sessions may not be as physically challenging to athletes when compared to competitive match play.

2.5. Consequence of Injury

2.5.1. Financial

Previous research has shown that the escalating financial costs associated with sports injury assessment, treatment, and patient services makes it crucial that the most effective, economic and best possible actions are applied to reduce injuries and lower costs to this sector (Finch et al. 2009). It is estimated that the costs associated with sporting injuries World-wide to be \$1 billion, with between 3 to 5 million injuries taking place in the United States alone each year (Murphy et al. 2003). Not only are financial implications an issue to the health sector but, most importantly to the players themselves with respect to days lost from school to attend medical appointments.

In 1997 the SportSafe Australia framework was established, and it recognised sports injuries as an undesirable outcome of physical activity and highlighted the socioeconomic impact on society with respect to treatment costs, time lost from employment and disability benefit. An annual estimate of the cost of sports injuries in Australia was reported to be AUS\$1.83 billion (Finch et al. 2009).

The GAA like other sporting bodies pay a heavy price for injuries with soaring insurance premium rates and claims. In 2015, the GAA paid out over €8m on injury claims and expenses following accidental injury sustained in the course of playing and/or participating in official training for Gaelic games (GAA Fincial Statement, 2015). It was also reported in a review of the GAA's injury claims scheme between 2007 – 2014, that over €64m was paid out on more than 58,000 injuries (Roe et al. 2016). Throughout the 8-year time period of this investigation, there was an average of 19,892 registered GAA teams in Ireland, which gave rise to an average of $7,255 \pm 2,064$ claims of $\text{€}1,158 \pm \text{€}193$ annually (Roe et al. 2016). This resulted in 0.36 ± 0.10 claims annually per registered team, equivalent to 2.92 ± 0.78 injury claims per affiliated club within the entire GAA association. The majority of claims registered throughout the 8 years were from adult players, with 85% compared to 15% for youth players. Gaelic football (74%) claims were more frequent than hurling (26%) and resulted in 5,395 and 1,859 average annual claims for Gaelic football and hurling respectively. In conclusion, this study reported that lower limb injuries were found to be the most frequently injured part of the body, accounting

for 60% of all claims during the investigated period. There was a significant correlation found between the number of lower limb injury claims and annual injury claim expenses ($r = 0.85$, $P = .01$), which means that by reducing lower limb injuries, it will help to reduce injury claim expenses.

2.5.2. Time Lost from Play

Details on injury incidence, participants, time lost from play are provided in **Table 1**. Not being able to take part in their chosen sport is a significant consequence for any participant that sustains an injury in the sporting context. Following investigations into various multidirectional field sports, rugby (54%) displayed the highest percentage of injuries that required players to be absent from play for between 1 and 7 days, compared to soccer (50%), Gaelic football and hurling both 45%. Likewise, rugby also had the highest number of injuries incurring the longest time lost from play with 20% followed by soccer at 15%, with Gaelic football and hurling 13% and 10% respectively. Rugby, however, classified severe injuries as equal to, or more than 21 days lost from play, whereas the other three sports were equal to, or more than 28 days absent from play. The results of the lacrosse study was not included here, as that investigation was the only one that included youths under 15 years old. However, it is worth noting that the adolescent lacrosse study (Kerr et al. 2016) established 83.9% of injuries reported, resulted in no time being lost from play, which is interesting considering lacrosse, like hurling is a fast, physical, contact game. This is in contrast to a previously reported GAA study which established 86% of all injuries encountered during a four year investigation into Gaelic football caused in excess of one weeks absence from play (Murphy et al. 2012).

The same author also investigated incidences of injury in hurling (see **Table 1**) throughout a one-year period using the same classification system for time loss (Murphy et al. 2012). However, the results of this study showed that the majority (45%) of injuries received in hurling were mild with up to one week absence from play. Moderate injuries resulted in 45.5% with severe injuries resulting in players missing over 4 weeks of competition accounting for 9.5% of all injuries. Following these two investigations, it

appears Gaelic football injuries incur a greater time loss from competition than hurling. However, the Gaelic football study was carried out over four seasons with 851 subjects whereas the hurling study was conducted over 34 weeks (1 season) with only 127 subjects tracked for injuries.

Table 1: Time Loss from Play - Study Characteristics and Results

| Author(s) | Participants | Incidence of Injury | Time loss | Other Details | Conclusions |
|-------------------------|--|---------------------------------------|--|--|---|
| Brooks et al. (2005) | 546 rugby union players from 12 clubs. | 91 injuries per 1000 player-hours | Each injury x 18 days lost time | 18% Recur. inj. More severe (27 days) / new inj. (16 days) | 23% of players unavailable because of match inj. |
| Stubbe et al. (2015) | 217 profess. soccer players, 8 Dutch clubs | 6.2 injuries per 1000 player-hours | Inj. time loss from 1 - 752 days, median of 8 days | Knee inj. ↑ days lost from play (45 days) | Inj. risk high; 62.7% sustained inj. |
| Kerr et al. (2016) | 550 lacrosse (9–15 years) 8 leagues | 12.98 injuries per 1000 athletic exp. | 83.9% time loss of <24hrs | stick contact (35.5 %) and ball contact (14.2 %). Injury | lower extr. (45.2 %), contusions (51.6 %). |
| Murphy et al. (2012) | 127 adult hurlers. 4 teams, 1 year | 11.48 injuries per 1000 player-hours | 45% inj. 1-7 days lost 45.5% 7-28, 12% 28 + days | 70.1% Lower-limb. 16.5 % hamstring strain | Match inj. 55.4% Training 41.7% |
| O' Connor et al. (2015) | 292 male adolescent Gaelic footballers and hurlers | 4.87 injuries per 1000 hrs. | Hurling minor inj. 61.7%. Football mod. 20.8%, severe 37.5% | Lower limb football 74.7%, hurling 58% | Match inj. footballers 9.26/1000h hurlers 11.11/1000h training 2.69 & 3.01/1000h. |

One interesting detail to note from the results established from the rugby investigation was that, 23% of a club squad could potentially be unavailable for selection during some part of a playing season because of injury. However, O' Connor et al. (2015) showed from their epidemiological study on adolescent hurling players, that one-third (33%) of players received an injury and could potentially be unavailable for selection during a season. Another issue to note when comparing these studies, the rugby investigation

was carried out over two seasons, Gaelic football was investigated throughout a four-year time period, with soccer and hurling data collected during one playing season

2.5.3. Psychological Effects of Injury

The numerous physical health benefits of playing sport are well known, however in recent times, it has been noticed that participation in sport can have a positive effect on a person's mental health. However, sport injuries could potentially have the opposite effect on a player's mental health. The WHO defines health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (World Health Organization 2015). It is evident from this definition that it includes the mental health and well-being of an individual and not just the physical health. Participation in sport can contribute positively to a players' mental health, by helping them to cope with everyday pressures or problems in their lives as well as helping them feel good about themselves.

The possible psychological side effects following injury are a concern for coaches, athletes and their families. Clement et al. (2015) formerly indicated that sports medical professionals who work with injured players during the rehabilitation stage can be of assistance with both the physical and psychological developments following injury. A previous investigation explored the opinions injured players held, on the roles of medical professionals facilitating sport injury rehabilitation (Arvinen-Barrow et al. 2014). Interviews were carried out on ten elite male soccer and rugby union players (aged 22.4 ± 3.4 years). All the injured players interviewed remarked that injuries had an emotional consequence on their lives. The emotional responses reported were feelings of shock and disbelief, feeling low and depressed, players also described being "upset", "gutted" and "annoyed" following injuries. The two most frequent emotional responses conveyed by the injured players were of self-doubt and frustration.

Other studies concur with these findings, Clement et al. (2015) investigated the psychosocial responses during the different stages of injury rehabilitation and reported several commonalities among eight previously injured athletes. The athlete's initial reactions to their injury were predominantly negative which had an effect on the

subsequent emotional responses, which were also largely negative. The athletes reported feeling frustrated with the progression of the rehabilitation phase. During the final stage of injury rehabilitation, the return to play phase, athletes reported both positive and negative responses. On the one hand, players described feelings of nervousness of re-injury, anxiety, as well as positive excitement. These feelings also reflected their cautiousness and behavioural actions when they returned to sport.

A further study investigated the frequency, management and perceptions of 1,002 non-elite athletes, having received 562 sport related injuries (Grice et al. 2014). Interestingly, athletes who were previously injured were less likely to contact a medical professional for injury related advice than those with no previous injury (45% v's 64%). It was also reported that these athletes were more likely to continue playing despite receiving an injury (51% v's 37%). Athletes were mostly concerned with the short-term issues around injuries with only 32% having any concerns about potential long term problems such as joint complications, namely osteoarthritis.

It is imperative that we keep players on the field of play mentally and physically healthy while playing sport and try to reduce the likelihood of injuries. Consequently, mental illness is a significant public health concern. By 2020, it is expected to account for 15% of worldwide burden of disease, which by then would make it the leading disease affliction (Biddle & Asare 2011). Therefore, anything that can be done to maintain mental and physical well-being in our adolescent athletes must be embraced.

2.6. Injury Prevention

Injury prevention programmes are a fundamental part of any team's preparation for competition (Owen et al. 2013). Worldwide injury prevention programmes in team sports have been developed in response to the injury rate upsurge as previously discussed (O'Brien & Finch 2014). According to the International Olympic Committee (IOC), the goal is clear;

Develop healthy, capable and resilient young athletes, while attaining widespread, inclusive, sustainable and enjoyable participation and success for all levels of individual athletic achievement (Bergeron et al. 2015).

Hurling can be described as a high intensity, running, contact sport that involves phases of continuous physical activity, including unpredicted, explosive and multidirectional movements with player-to-player physical contact (Blake et al. 2014). At all levels, the demands of regular training and matches performed during the competitive season can make players susceptible to injury. Adolescents can be at particular risk of sporting injuries because of increased levels of activity at a time of key physiological development (Abernethy & Bleakley 2007). Losing players to injury during a season can obstruct a team's chances of success, especially if playing numbers are limited. O' Connor et al. (2015) established that one third of adolescent players received an injury during a playing season, with over a quarter of these players sustaining a subsequent injury during the same season. This high rate of re-injury possibly suggests that adolescent players could be returning to play without proper rehabilitation following the initial injury, and in doing so is likely to increase their injury risk further.

Recently, there has been a growing interest in strategies to prevent injuries in team sports, and in particular the implementation of injury prevention programmes, specifically intended to reduce non-contact musculoskeletal injuries. Some examples of these injury prevention programmes are; 'FIFA 11+', 'PEP', 'Knaekontroll', 'HarmoKnee' and 'PAFIX' and the GAA15. These programmes generally consist of a number of exercises and fundamental movements, which target sport specific injury risk factors and incorporate a mixture of balance, flexibility, plyometric, agility, strength and sport specific movements.

2.6.1. Injury prevention Framework

The topic of sports injury investigation and management has progressed over the years with advances in sports medicine. There have been improvements in the areas of injury diagnosis, treatment, rehabilitation and identification of intrinsic risk factors for at risk athletes. However, the extent of the sports injury problem calls for appropriate preventative action based on the results of epidemiological investigations (van Mechelen et al. 1992). It has been suggested that members of sports clubs, such as athletic trainers are in the ideal position to carry out injury surveillance (Ekegren et al.

2015). In Australia, for example, sports trainers in Australian rules football are now encouraged to consistently record injury data for their clubs using various online means or paper forms. It is anticipated, that by scrutinising the data acquired via the online tools, it will eventually educate and promote injury prevention strategies and programmes within their sport (Ekegren et al. 2015). In addition to this work, the National Guidance for Australian Football Partnerships and Safety (NoGAPS) project was established to help identify the elements that shape the transformation from investigative evidence into sports injury prevention strategies and programmes. NoGAPS provides evidence for the use of an injury prevention exercise programme in community based Australian rules football to help reduce lower limb injuries and also to evaluate the resources required for the effective implementation in community sport (Finch et al. 2011).

Subsequent to examining the various concepts of injury prevention, van Mechelen (1997) stated that the first thing that needs to be done, is determine and describe the extent of the injury problem in the sport followed by the mechanisms of injury. Measures then need to be taken to reduce the risk and severity of future injury followed by a review of the measures taken to affect the change (see **Figure 4**).

In 2006, it was suggested that a number of limitations existed to van Mechelen's original four stages of sequence to prevent sports injury (Finch, 2006). It was acknowledged that this four-stage model of injury prevention was a significant process by clearly defining the direction required and the evidence needed to establish a starting point for injuries and their underlying risk factors. However, it was suggested that a need for research into the implementation of injury prevention measures was needed. For an injury prevention strategy to be successful, it was suggested, that it had to be sport specific, be adopted and regularly used by the athletes and sports to which it is designed. Following the publication of this study (Finch, 2006), a new sports injury research framework was proposed (see **Figure 5**).

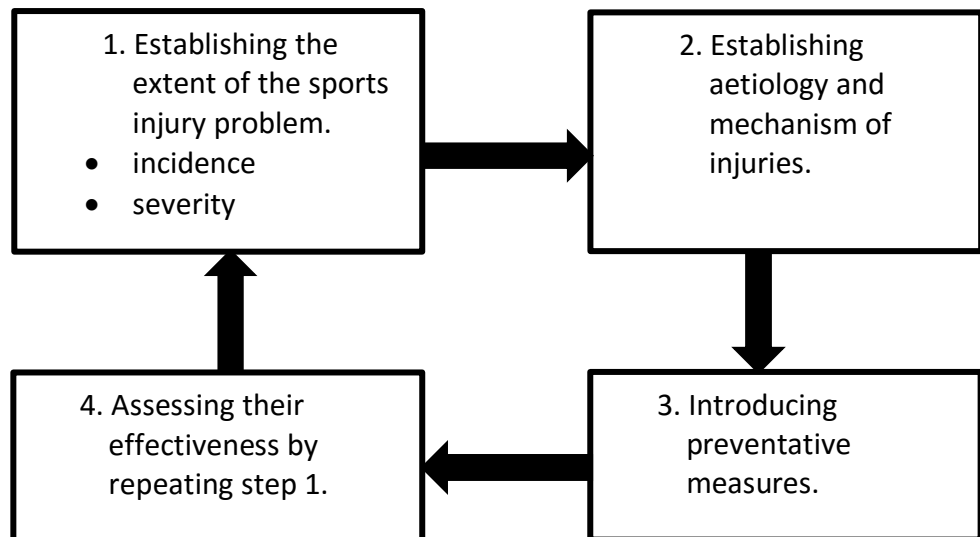


Figure 4: The sequence of prevention of sports injury (van Mechelen et al. 1992).

The Translating Research into Injury Prevention Practice framework (TRIPP) is a model that is built on confirmation that only research evidence can, and will, be adopted by players, coaches and sporting associations to prevent injuries (Finch 2006). Furthermore, it is suggested that future improvements in injury prevention strategies will only succeed if research is directed towards understanding the implementation, efficacy and effectiveness of injury prevention programmes. The TRIPP framework proposed a series of necessary steps that Finch stated were needed to establish an evidence base for the prevention of injuries. Another conceptual framework model, developed by William Haddon Jr. called the ‘Haddon Matrix’, also recognised the importance of the implementation of any preventative programme (Runyan 1998).

| Model | TRIPP |
|-------|--|
| Stage | |
| 1. | Injury surveillance. |
| 2. | Establish aetiology and mechanism of injury. |
| 3. | Develop preventive measures. |
| 4. | “Ideal conditions”/scientific evaluation. |
| 5. | Describe intervention context to inform implementation strategies. |
| 6. | Evaluate effectiveness of preventive measures in implementation context. |

Figure 5: The Translating Research into Injury Prevention Practice (TRIPP) framework. (adapted from Finch, (2006).

The Haddon framework was developed by applying basic public health principles to the problems of traffic safety and since then, has been used as a tool to assist in developing ideas to prevent injuries. Similar to the fifth stage of the TRIPP framework (Describe intervention context to inform implementation strategies) suggests how understanding the results of research can be transferred to real-world programme implementation in sport. This stage recommended the understanding of the best way to train and promote evidence-based injury prevention programmes to sporting associations and their participants. Stage two of the TRIPP framework (Establish aetiology and mechanisms of injury) requires rigorous injury data reporting for the enhancement of up-to-date injury preventative strategies (Ekegren et al. 2015).

2.6.2. FIFA11

Soccer is undeniably one of the most popular team sports in the world. The International Federation of Association Football (FIFA), reported that there was a playing population

of 265 million male and female soccer players worldwide (Breda 2016). This amounts to approximately 4% of the world's population that are actively involved in soccer. Male soccer players (90%) make up the largest part of the playing population, with the majority (54.7%) of these youth (under 18 years) soccer players (Breda 2016). Soccer is a game that requires moderate to high levels of aerobic conditioning along with good anaerobic power, good agility, technical and tactical skills. In 2006 the FIFA Medical and Research Centre (F-MARC) in cooperation with the Santa Monica Sports Medicine Foundation (SMSMF) and the Oslo Sports Trauma and Research Centre (OSTRC) developed a soccer specific injury prevention warm-up programme called the FIFA 11+ (Bizzini et al. 2013). This warm-up programme was designed to prevent injuries in amateur soccer players and consisted of running activities, muscle activation, balance, strength and core stability exercises. Numerous studies have been carried out around the world into the effectiveness of the FIFA 11+ injury prevention programme (Grooms et al. 2013; Owoye et al 2014; Silvers-Granelli et al. 2015).

A cluster randomised controlled trial carried out by Owoye et al (2014) investigated the efficacy of the FIFA11+ injury prevention warm-up programme in male youth soccer players. This consisted of 414 players from 20 teams aged 14 to 19 years. Players were randomised into one of two groups, an intervention group using FIFA11+ warm-up programme or a control group performing their usual warm-up routine. Results of this study established that 130 injuries were sustained by 104 players (25%) out of the total cohort of 414 players. Compliance of the intervention injury prevention programme was 60% and 74% for team and players respectively. The overall rate of injury was reduced significantly (↓41%) in the intervention group when compared to the control group. Lower extremity injuries were also reduced significantly by 48% between the two groups. Injuries in this investigation were based on the players own subjective assessment, and were not described in the research by type, but by location, aetiology, mechanism and severity. Furthermore, the implementation of the intervention programme was done by the team coaches with only occasional supervision by research physiotherapists, so the extent to which intervention teams used the programme throughout the trial period was uncertain.

These results are consistent with other investigations that explored the efficacy of the FIFA11+ injury prevention programme. A study examining 1,525 male collegiate soccer

players from 61 teams who were randomly assigned into either an intervention group consisting of 27 teams (675 players) or a control group of 34 teams (850 players). The intervention teams used the FIFA11+ warm-up two to three times per week over the course of one collegiate season with the control group applying their usual warm-up routine. The intervention group reported 285 injuries, compared to 665 injuries in the control group. The injury incidence rate was also lower in the intervention group (8.09 injuries per 1000 hours of athlete exposures) compared to the control group (15.04 injuries per 1000 hours of athlete exposures). The intervention group also missed less days from play due to injury (2824 days; average 9.94) in comparison to the control group (8776 days; average 13.20) (Silvers-Granelli et al. 2015). This investigation was carried out over one collegiate soccer season, which was 5 months; it could be suggested that not enough time was allowed for proper coaching and athlete learning of the FIFA11+ programme prior to the season commencing. Furthermore, each team was educated on the content, structure and implementation of the programme by an online website with no direct contact between team coaches and the lead researcher.

While investigating the FIFA11+ warm-up and lower extremity injuries in male soccer players, Grooms et al. (2013) concluded that the programme reduced the overall risk and severity of injuries in one American collegiate soccer team. This study consisted of monitoring one soccer group of 41 players (aged 18 – 25 years) over two seasons. The first season entailed players using their normal warm-up routine before play with season two using the FIFA11+ injury prevention warm-up routine. Results displayed season one (normal warm-up) with an injury rate of 8.1 per 1000 hours of exposures and 291 days lost, and season two (FIFA 11+) 2.2 injuries per 1000 hours of exposures and 52 days lost from play. Overall the intervention season had a reduction in relative risk of lower extremity injury of 72%. One limitation of this investigation was it comprised of only one team over two seasons, with several players involved in one season only.

2.6.3. The PEP Programme (Prevent injury and Enhance Performance)

The PEP injury prevention programme was developed by the Santa Monica Orthopaedic and Sports Medicine Research Foundation to help reduce the incidence of anterior

cruciate knee ligament (ACL) injuries in soccer, and in particular the rising number of non-contact ACL injuries in female players. The PEP programme takes place before sport activity, requires no special equipment and lasts approximately 15 – 20 minutes. The warm-up routine consists of 20 exercises in five categories; flexibility, plyometrics, strength, agility and avoidance of vulnerable positions.

Previously researchers investigated the effectiveness of the PEP programme in preventing injuries in female athletes and concluded that it may have a direct benefit in decreasing the number of ACL injuries in female soccer players (Mandelbaum et al. 2005). This study was carried out over two seasons with season one consisting of 2,946 players (intervention group = 1,041 players; control group = 1,905 players) from 147 teams and season two (intervention group = 844 players; control group = 1,913 players) from 157 teams. All subjects were female soccer players aged 14 – 18 years, and participated in either the intervention warm-up or their normal warm-up routine before competition over a 2-year period. Results from the first season showed there was an 88% reduction in ACL injury in the intervention group compared to the control group. The following year, season two showed a 74% decrease in ACL injuries in the intervention group compared to the control group. This demonstrates the effectiveness of such a programme at decreasing the incidence of noncontact ACL injuries in female athletes, however it should be noted that this current study is focusing on male subjects and not solely looking at ACL injuries, but lower extremity injuries in general. However, there are lots of similarities between the two sports, soccer and hurling, with both being high intensity multidirectional contact field sports. It is also worth noting that Mandelbaum's investigation stated that the number of female athletes suffering non-contact ACL injuries exceeded male athletes by 2 to 8 times which corroborates with other studies (Quatman & Hewett, 2009; Stevenson et al. 2014).

An additional study investigated noncontact ACL injuries in 1,435 female soccer players (852 control group; 583 intervention group) in a randomised controlled trial over one season (Gilchrist et al. 2008). Results showed that noncontact ACL injury rates among the intervention group to be 3.3 times less than that of the control group (70% reduction), with the overall rate 1.7 times less (41% reduction). The rates of noncontact ACL injuries during matches were reduced by more than half in the intervention group with no ACL injuries reported during training in the intervention group compared to 6

among control players. Notably, no ACL injuries occurred in the intervention group during training, compared to 6 in the control group, with game related ACL injuries being reduced by more than half in the intervention group. Additionally, it was reported that intervention players with a previous history of ACL injury were significantly less likely to suffer another ACL incidence compared to players in the control group.

Both of these investigations involving large numbers of female soccer players established significant reductions in ACL injuries following the implementation of an injury prevention warm-up programme. Because of the severity of the ACL injury, large subgroups are required, and despite 1,435 subjects being involved in the Gilchrist et al. (2008) study, only 25 ACL injuries occurred. It was noted, that following power calculations before this investigation started, that 100 teams would be needed to fully scrutinize the groups, however, time and funding prohibited more teams being included in this research. Another factor to note, was the Mandelbaum et al. (2005) study was a nonrandomised prospective study, whereas the Gilchrist et al. (2008) study was a randomised control trial. It could be possible that the selection process Mandelbaum used may have affected the reduction in ACL injuries in the intervention group, as this group volunteered to participate and might have had a superior interest in preventing injuries to begin with. On the other hand, the players in the control group had no knowledge of the research design and were unaware of the PEP injury prevention programme, which was only identified to the team trainer.

2.6.4. The “Knäkontroll” (knee control) Injury Prevention Programme

Similar to other injury prevention programmes, the knäkontroll programme contains exercises focusing on knee control as well as core and trunk stability exercises. The programme consists of six exercises; single leg squat, pelvic lift, double leg squat, the plank, lunges, and jumping and landing exercises. Each of the six exercises are subdivided into four further stages of progression to increase the level of difficulty.

The knäkontroll programme was used to address the growing acute knee injury incidence in 4,564 adolescent female soccer players (aged 12 – 17 years) from 230 Swedish soccer clubs during one season (Waldén et al. 2012). This study investigated

two outcome measures; the primary outcome was the rate of ACL injury; and the secondary outcome was the rate of severe knee injury, resulting in more than four weeks' absence from play. Results showed that 7 players (0.28%, intervention group) and 14 players (0.67%, control group) sustained an ACL injury. A 64% reduction in the rate of ACL injury was reported in the intervention group when compared to the control group. To the best of the authors knowledge, this research was one of the biggest randomised controlled trials on sports injury prevention, involving more than 4,500 players (Waldén et al. 2012).

2.6.5. PAFIX Programme (Preventing Australian Football Injuries with Exercise)

Australian rules football is one of the most popular team sports in Australia with an estimated 2% of the general public (population 24.6 million) and up to 3% of the entire male population (12.3 million) participating. Similar to Gaelic games, it is a high intensity, high velocity, multidirectional contact field game, where the aim is to score more than the opposition (O' Connor et al. 2015). These participation rates rank Australian rules football as the 13th most popular physical activity in Australia (Finch et al. 2009). Unfortunately, knee injuries are a major concern for Australian football players and as a result, the preventing Australian football injuries with exercise (PAFIX) study was established in 2006.

A clustered randomised controlled trial in community Australian football selected players from 18 non-elite clubs to participate in either the intervention (679 players) group or the control (885 players) group (Finch et al. 2015). The intervention group received a neuromuscular exercise training programme as part of their regular team training sessions to be completed twice weekly for the 8 weeks of pre-season and 18 weeks during the season, while the control group was furnished with a 'sham' warm-up programme comparable to their normal routine undertaken at training and matches. The study reported 1,032 injuries of which 773 were match injuries with the lower extremity the most common body region injured accounting for 50.2% (intervention 46.3%; control 53.2%) of all injuries. The knee was the most frequently injured lower

limb with 12% of all injuries (intervention 9.6%; control 13.9%). Results following a cluster-adjusted injury incidence rate signified a 22% reduction in lower limb injuries in the intervention group compared to the control group. The cluster-adjusted knee injury incidence rate was just less than significant, with 50% reduction in the intervention group compared to the control group players.

2.6.6. The GAA15 Injury Prevention Programme

Since 2006, the GAA has been developing an injury prevention framework for Gaelic games. During the first phase of this framework, the GAA established the National GAA Injury Database, where all inter-county team backroom medical personnel were asked to register injuries throughout the playing season. This database formed the archive for a prospective cohort study (Blake et al. 2014), where the aim was to report injury incidence and type incurred by a total of 856 elite adult hurling players from 25 senior county teams between 2007 and 2011. Injury incidence, nature and mechanisms were documented by team physiotherapists and/or physicians through a secure online data collection portal. Injuries were classified into time loss injury rates per 1000 hours of training or matches along with injury proportions. This information provided a clear picture of the amount, type, nature and mechanisms of injuries sustained in adult hurling. At the same time, Murphy et al. (2012) carried out a descriptive epidemiological study over a four-year period (2007 to 2010) on data recorded in the GAA injury database from 851 senior (adult) county Gaelic football players. From this research, it has been reported that two-thirds of GAA players may potentially sustain an injury and one-third will sustain more than one injury in any season. One quarter of all injuries reported were a recurrence of an existing injury or old injury. More than 75% of injuries were to the lower extremities and mostly consisted of soft tissue injuries, with hamstring injuries being the most frequently injured site (17-23%). Two-thirds of injuries were non-contact injuries with the remaining injuries as a result of direct player-to-player contact, causing injury. The non-contact injuries were commonly reported secondary to sprinting, jumping, landing and rapid changes of directions (Murphy et al. 2012; Blake et al. 2014).

The second phase of this injury prevention framework consisted of investigating the risk factors potentially responsible for injury in Gaelic games. Following research into non-contact injuries, poor player neuromuscular control was identified as a possible risk factor, which can be described as a player's ability to stabilize, control and withstand the physical nature of a sporting activity (Stevenson et al. 2014). It has been reported by Stevenson that neuromuscular training programmes may potentially modify the risk factors and reduce lower extremity injuries.

Subsequently, the GAA developed a specific injury prevention training programme (GAA15) in conjunction with its Medical, Scientific and Welfare Committee in response to the growing injury concerns. This programme consisted of a 15-minute warm-up, similar to the FIFA 11, which was designed to integrate into current team training practices with minimal to no equipment required. The GAA15 has three different sections involving six types of activity with a total of nineteen exercises, which are performed at the beginning of training and match sessions (see **Table 2**).

A recent randomised cluster trial examined whether the GAA15 could improve risk factors for lower extremity injuries in male hurling players and Gaelic footballers, following an 8-week randomised cluster trial (O'Malley et al. 2016). Four collegiate Gaelic games teams were involved in the research with one hurling and one Gaelic football team allocated to an intervention group (n=41) with matched teams allocated to a control group (n=37). The intervention teams used the GAA15 programme twice weekly for the 8-week trial period with the control group participating in their normal warm-up routine. Jump-landing technique (Landing Error Scoring System) along with lower limb stability (Y-Balance test) were analysed before and after the 8-week intervention period to see if the GAA15 programme had an effect on the players neuromuscular control. Balance and jump-landing technique both displayed significant improvements in players from teams that implemented the GAA15 compared with the teams who completed their normal warm-up routines.

Table 2: The GAA15 – Structure of the injury prevention warm-up programme.

| | |
|--|--|
| The GAA15 has 3 Sections comprising of six types of activity with a total of 19 exercises. | |
| SECTION 1 – Running | |
| PART A: Running exercises at slow speed | Slow runs forward, 20m x 2. Hip out movement and jog, 20m x 2 Hip in movement and jog, 20m x 2 Jog with heel flicks, 20m x 2 Jog with toe touches, 20m x 2 50% run forward and jog back, 20m x 2 80% run forward and jog back, 20m x 2 |
| SECTION 2 - Improving the Mechanics and limiting risk of injury | |
| PART B: Strengthening exercises focusing on the core and legs | Single Leg Bridge x 8 reps Forward lunge with gluteal activation x 6R Reverse Lunge x 6 reps Squats (pelvic mobility) Core Drill (30 sec) x 2 sets (Front & side plank) |
| Part C: Sport Specific Balance | Single Leg Lunge |
| Part D: Jumps | Counter movement jump Double leg x 8 reps, 2 sets Box jumps x 8 reps, 2 sets Lateral Jumps to single leg land, side to side x 8 reps, 2 sets |
| Part E: Hamstrings. | Nordic lowers x 3-5 reps |
| SECTION 3 - Sports Specific Movement | |
| Part F: Sport Specific | 80% max Speed runx20m, slow jog back x 2 Plyometrics: Bounding slow jog back. X 2 Plant and push drill while jogging. |

There is a wealth of evidence from previous research (Mandelbaum et al. 2005; Waldén et al. 2012; Owøye et al. 2014; Finch et al. 2015) that IPPs can display positive results, with respect to injury reduction. However, evaluating how athletes respond to training programmes (athlete monitoring) along with the recording of injuries remains challenging and it is suggested that this should be a fundamental requirement for all sporting participants.

2.7. Athlete Monitoring

Athlete monitoring entails recording what athletes accomplish in training or games, for the purpose of enhancing the connection between coach and athlete (Foster et al. 2017). Collecting information and recording injury data for researchers has become a very labor-intensive and time consuming pursuit.

The consensus at present suggests that there is no, single 'one-size-fits-all' injury definition (Clarsen & Bahr 2014). It has been recommended that three alternative definitions of recordable incidents be used in such epidemiological research these are: i) all complaints, ii) medical attention and iii) time loss. Of all of these, time loss has been widely used and accepted in the research as it is easy to identify (Clarsen & Bahr 2014). An advantage of self-reporting surveillance systems is that no medical expertise is needed to apply a time-loss definition. Medical attention and diagnosis in surveillance is laden with bias due to differing personal opinion and inconsistency in medical terminology as well as medical personnel availability and inconsistency in assessment and recording. Injury occurrence, utilizing the time loss definition can be recorded by players themselves or other non-trained individuals and therefore is of particular benefit in large cohort studies involving young and recreational athletes. With the increased availability of online report forms and short messaging service (SMS) systems, as an alternative to the traditional way for self-reporting player exposure rates and injuries in research, accessibility and reach to participants has increased (Taylor et al. 2012). An advantage of using this type of self-reporting is the speed with which the data can be obtained as well as optimising accurate recall from the player. Like all surveillance methods however there are advantages and disadvantages. The limitations to self-reporting injury surveillance lies with interpretation of injury definitions and data completion and compliance (Clarsen & Bahr 2014). However, with clear definitions and education to the participants these limitations can be minimized.

2.7.1. Short Messaging Service (SMS) Athlete Monitoring

Short messaging service (SMS), or mobile phone text messaging, was used to report on injuries in four Australian rules football clubs consisting of 139 players (Ekegren et al. 2014). Each of the players in this investigation received an SMS text at the end of the weekly round of matches asking if they had been injured in the preceding week. This investigation observed the number of self-reported SMS injuries, rates of player response, and time of player SMS response. Outcomes reported 167 injuries were received by SMS throughout the season. Player response rates varied between 90% to 98% and with those that replied on the same day, 47% did so within 5 minutes. This study concluded that the number of injuries reported by SMS was similar to previous investigations in Australian Rules football and this method of self-reporting of injuries provided a quick response rate. A couple of issues to note with this investigation, firstly, there was a cost involved for each player to message back the researcher which is something that cannot be assumed is suitable to everyone. Also, only 44% of all players registered with the four clubs were available on the recruitment day, this obviously had an effect on overall compliance rates.

Saw et al. (2015) investigated the factors which may affect implementation, understanding and compliance of a newly implemented athlete self-report system over a 16-week period. An electronic survey was completed by 131 athletes at week 1 and at week 16 on their experiences and perceptions of athlete self-reporting measures. 70 athletes (84%) attempted to complete the online self-report system, with team sport players who were encouraged by their coaches, the most compliant. Compliance for individual athletes and team players without the encouragement of team coaches was 28% and 8% respectively. Results showed that team players were more likely to be compliant for the benefit of the team rather than themselves. This investigation displayed the complexities of achieving quality compliance when using online athlete self-reporting measures. Generally, player experiences and perceptions of using online self-reporting measures were highly varied, however, some common ground existed within a sporting context. In particular, making sure that whatever self-reporting measure is being used, that it meets the needs of the self-motivated athlete with as little burden as possible, and that the team athlete sees value from the data output. This

study recommended that the implementation of an online self-reporting measure be tailored to the sport so that the appeal is increased and any unappealing aspects are lessened.

2.7.2. Rate of Perceived Exertion (RPE)

Internal training loads can be described as an athlete's acute experience of what happens in a training session or match, whereas, external training loads are what is actually completed in that session (Foster et al. 2017). Sports coaches and trainers can measure internal training load by having players rate their perceived exertion (RPE) of sessions (Gabbett, 2016). This form of player monitoring is the ability to evaluate the intensity and quality of a session. Following a match or training session, athletes provide a rating of 1 to 10 (see **Figure 6**) on the intensity of the session, with 1 being an easy session and 10 an extremely demanding session. This numerical rating is then multiplied by the duration (mins) of the activity to provide training load or training units as described by Foster et al. (2001). These units generally range between 300 to 500 for lower-intensity sessions with high-intensity sessions potentially reaching anywhere between 700 to 1000 units, depending on an athlete's physical fitness and session duration. According to Gabbett (2004), a strong relationship exists between excessive training units, obtained from session RPE, and injury rates during training sessions. This evidence was acquired from a prospective study of 79 semi-professional rugby league players during training and match competition in the course of the 2001 season. Gabbett (2004) established that by reducing training units, it noticeably reduced the rates of injury in 220 sub-elite rugby league players during a 3-year period. In this investigation, the training loads were significantly lower during the 2002 and 2003 seasons when compared to the 2001 playing season. Furthermore, it was established that injury incidences were significantly higher following the 2001 (156.7/1000hrs) pre-season than the 2002 (94.4/1000hrs) and 2003 (78.4/1000hrs) seasons.

| Rate of Perceived Exertion Scale | |
|----------------------------------|--------------------|
| 1 | Nothing |
| 2 | Very Easy |
| 3 | Easy |
| 4 | Comfortable |
| 5 | Somewhat Difficult |
| 6 | Difficult |
| 7 | Hard |
| 8 | Very Hard |
| 9 | Extremely Hard |
| 10 | Exhausted |

Figure 6: Rate of Perceived Exertion (RPE) Scale

Foster et al. (2001) investigated individual players RPE as a way of monitoring exercise training. This study evaluated the ability of the player session RPE rating system method compared to an objective standard based heart rate system to quantify training during pro-longed and non-steady-state exercise. The research was structured in two parts, with part one consisting of 12 well-trained recreational cyclists performing an interval cycle session on a cycle ergometer. The second part consisted of 14 members of a collegiate basketball team who were monitored during basketball training and competitive matches. The results of this study displayed a highly correlated relationship between the session RPE and the objective heart rate monitoring system, therefore, it suggests that this method of athlete monitoring may be a useful practice for measuring training load in a wide variety of sports (Foster et al. 2001). Despite using two different groups of subjects and performance tests, this research established a similar relationship between the session RPE score and the heart rate method, however, in both groups the absolute score was significantly higher with the session RPE method. In conclusion, this study supported the use of the session RPE training load monitoring system during high intensity interval training sessions in addition to team sport training and match competition. Furthermore, it established that the RPE athlete monitoring system is easy to use, reliable and consistent with objective physiological indicators (Foster et al. 2001).

In professional Rugby Union, the association between in-season training-load and risk of injury was investigated in 173 players from four English Premiership teams (Cross,

2015). Player training-load (session RPE x session duration in minutes) was recorded for all field and gym sessions. This study concluded that players had an increased risk of injury if they had a high cumulative one-week training load (1245 training units) or if they had a large change (1069 training units) in week-to-week training loads over a four-week period. Furthermore, it established an increased risk of injury was observed in players that exhibited high cumulative four-week training loads in excess of 8651 training units.

Similar results were reported from a study in forty six Australian Rules footballer players (mean \pm SD age of 22.2 ± 2.0 years) from one club over one season (Rogalski et al. 2013). Session RPE and training loads were calculated from training and competitive matches, with injuries recorded when they occurred. Rolling weekly training load quantities and changes in acute (week to week) training load were displayed in contrast to injury data. This investigation established that large weekly (greater than 1759 training units) and fortnightly (greater than 4000 training units) training loads were found to increase the risk of injury significantly in Australian football players. Changes of more than 1250 training units between weekly training sessions was also discovered to increase injury risk when compared to load changes of less than 1250 training units.

Previous studies have suggested that in order to reduce the risk of injuries in athletes, training and match load values of weekly loads and changes in week-to-week loads should be monitored (Rogalski et al. 2013; Cross, 2015). While Gabbett (2016) states that the problem may not be with the volume of training-load, but more likely the inappropriate training that is being prescribed. He also reaffirms the importance of monitoring training load and further indicates that the rapid and excessive increases in training loads may well be responsible for a large proportion of non-contact muscle injuries. As well as the longitudinal monitoring of training, competitive match load, injury and wellness details mentioned above, neuromuscular fitness and performance measures are also important considerations.

2.8. Neuromuscular Performance Measures

Before any sports season starts, baseline fitness and performance assessments often occur in order to determine normative data, generate a baseline for training and to distinguish fundamental physical characteristics of team athletes (Dawes et al. 2016). Various physical performance measures can be used to assess the physical capacity of team athletes (Lockie et al. 2015). Pre-participation and performance assessments, utilizing specific measures should be designed to be accurate, high in sensitivity and specificity, practical, suitable to apply to a large number of players, and the tests utilised must be safe to administer and acceptable to players (Garrick 2004). Athlete performance assessments need to be reliable, which refers to the reproducibility of the values of a test in repeated trials on the same athlete (Hopkins 2000). Performance tests are important indicators used by team coaches and trainers to design training phases, potentially identify players at risk of injury and as tests to guide players back to participation following injury. Sprinting and various different jumping tests are amongst the most popular performance assessments used to measure lower limb performance (Gonzalo-Skok et al., 2015). Sprinting tests include acceleration and maximal linear running speed over a set distance along with various tests for speed and agility. Jumping tests are used to assess lower-limb power and comprise of counter movement jump, squat jump, along with various single and double leg hop for distance tests. Both bilateral and unilateral jump tests have been used for player assessments due to the fact that both can be matched to sport specific movements and are reliable measurements (Gonzalo-Skok et al., 2015). A players ability to control dynamic neuromuscular movements along with being able to balance unilaterally on both legs are necessary for most multidirectional sports like hurling (Plisky et al. 2009).

2.8.1. Speed Performance Test

Speed and explosive power movements are considered to be fundamental attributes for success in youth team sports like soccer, rugby, and Gaelic games (Tomáš et al. 2014). In elite soccer, players can perform between 30 to 40 sprints of various distances during

a match and complete more than 700 twists and turns (Bloomfield et al. 2007). Tests for speed are typically used to assess players linear speed capabilities. Nagahara et al. (2014) established that sprinters involved in track athletics have been shown to continuously accelerate through the 50-meter mark during the 100-meter sprint event. However, in multidirectional team sports like rugby, soccer, and Gaelic games average sprint distances have been reported between 6 – 21 meters (Gabbett 2012; Andrzejewski et al. 2013). Hurling is similar to soccer and rugby with quick and explosive sprints over short distances, therefore it is important to assess players on distances specific to the sport. As the average sprint distances in team sports (rugby and soccer) appears to be between 6-21 meters, therefore, performing the 20-meter sprint test in this current investigation can be a good indicator of speed in adolescent hurling players.

2.8.2. Counter Movement Jump Assessment

Jumping can be described as a complex movement that requires good motor coordination between lower and upper body parts. The momentum of the lower extremity during various vertical jumps can be measured to estimate explosive physical characteristics of athletes (Markovic et al. 2004). A great deal of multidirectional team sports like hurling depend on a player's ability to produce force as quickly as possible, therefore, testing a players jumping performance can be beneficial for monitoring training effects and for pre and post season analysis (Kraemer & Newton 2000). The counter movement jump (CMJ) test is a straightforward way to calculate lower extremity leg power using prediction equations based on subjects body mass and jump height (Taylor et al. 2010).

2.8.3. Y-Balance Test

Athletes poor movement patterns, inadequate core stability along with deficits in functional balance have all been linked with increased injury risk (Engquist et al. 2015).

According to Butler et al. (2013), it is possible to predict the risk of injury by screening and measuring musculoskeletal movement and physiology markers. The Functional Movement Screen (FMS), Star Excursion Balance Test (SEBT) and the Y-Balance Test are screening tools that can be used to assess and measure fundamental movement. A screening system that detects athletes with poor unilateral and bilateral balance along with core stability deficiencies may be beneficial for assessing players for injury prevention. More recently, the y-balance test was created to assess unilateral balance and limitations of stability in just three directions in a more time efficient manner than the SEBT. Initial research using the y-balance test has been encouraging, Plisky et al. (2006) reported subjects with a difference of greater than 4cm in anterior left/right reach distance were 2.5 times more likely to sustain a lower limb injury. The y-balance test is completed on a device used to test balance, strength and flexibility during single leg stance similar to the SEBT. The test necessitates subjects to stand on one leg while pushing a marker with the opposite leg in the anterior, posteromedial and posterolateral directions without losing balance.

Gonell et al. (2015) investigated the relationship between y-balance test results and injury incidences in 74 (34 professional and 40 amateur) soccer players with a mean age of 20.89 years. Results showed that players who scored lower than the group average in each of the three directions were nearly two times more likely to incur an injury. Players that had a left/right leg score difference equal to, or greater than 4cm in the posteromedial direction appeared to be 3.86 times more likely to sustain a lower limb injury. However, there were limitations to this study, with the possibility of some minor injuries going undetected due to the fact that several different members of staff were involved in the collection of injury data. Furthermore, the side of the injury was not registered making it difficult to relate specific reach score to left/right leg.

Chapter 3: Reliability Study

3.1. Introduction

Prior to the principal study, intra-rater reliability was established for the measurement of physical performance measures to be utilised in the main study. Intra-rater reliability refers to the ability of the lead researcher to reproduce quantitative outcomes following a number of trials under the same experimental conditions with the same subjects (Gwet 2008). The following tests were carried out on three separate occasions: counter movement jump (CMJ), 20-meter sprint test and the y-balance test.

3.2. Participants

One GAA club was contacted via email and phone call and invited to participate in the reliability study. Five males (mean \pm SD; age: 19.80 ± 7.40 years) and three females (age: 14.67 ± 0.58 years) were randomly recruited from the GAA club via email and follow up phone calls, to take part in the physical performance testing. All subjects played hurling or camogie (female version of hurling) and were physically active on most days of the week. Participants attended an information gathering, where the details of the performance assessments and procedures were fully explained by the lead researcher. Ethical approval was obtained from the Institute of Technology Carlow Research Ethics Committee. Parental and participant informed consent (See **Appendix A**) was obtained from participants before any testing commenced.

3.3. Procedure

Subjects participated in three separate testing sessions, over a seven-day period. Days 1 and 2 were separated by 72 hours, with 96 hours separating day 2 and 3 (Nuzzo et al. 2011). During each testing session, subjects completed three CMJs, three 20-meter sprints and three y-balance tests on right and left legs. Maximum CMJ height and fastest sprint times were recorded from the three trials along with mean, normalised and composite values from the y-balance test on both legs. At the start of each testing

session, all subjects completed a warm-up (see **Appendix D**). On day 1, familiarisation of the three performance tests were completed with the lead researcher demonstrating the performance tests and then allowing each participant to practice until technique was satisfactory, which usually took three attempts.

During the first testing session, subjects' height (cm), weight (kg) and leg lengths were obtained and documented. Participant characteristics are displayed in **Table 3**.

Table 3: Physical characteristics of participants.

| Subjects | <i>n</i> | Age (y) | Height (cm) | Mass (kg) | BMI |
|--|----------|--------------|---------------|---------------|-------|
| Female | 3 | 14.67 ± 0.58 | 163.93 ± 4.62 | 64.17 ± 14.93 | 23.71 |
| Male | 5 | 19.80 ± 7.40 | 180.00 ± 6.56 | 79.06 ± 12.10 | 24.27 |
| Values are mean ± standard deviations. | | | | | |

3.4. Data Analysis

All data was analysed using the IBM Statistical Package for Social Sciences, Windows version 22.0 (IBM, Armonk New York). Intra-class correlation (ICC) was established for the three neuromuscular performance assessments to see if there was a correlation between testing days one, two and three. A two-way mixed effects ICC model was used with absolute agreement for average measures.

3.5. Physical Performance Tests

3.5.1. Counter Movement Jump

The vertical counter movement jump (CMJ), without use of arm swing or verbal encouragement, is a widely used performance test used to measure leg power and explosiveness in athletes (Focke et al., 2013). During each of the three testing sessions, three CMJs were performed on a contact mat (Just Jump, Probotics Inc., Esslinger Court, Huntsville, Ala.). The Just Jump contact mat (see **Figure 7**) provides data for the subjects

time in the air, from which the maximum jump height (peak vertical displacement achieved by the center of mass) was calculated using the following equation of uniform acceleration: $\frac{1}{2}g(t/2)^2$, where $g = 9.81\text{m/s}^2$ and $t = \text{time in the air (seconds)}$ (Moir et al. 2008).



Figure 7: The Counter Movement Jump (CMJ).

Results

Table 4: Intra-class correlations of the CMJ

| Test: CMJ | Jump Height (cm) ± SD | ICC Value | 95% CI |
|-----------------------|-----------------------|-----------|---------------|
| Counter Movement Jump | 44.0 ± 7.42 | 0.980* | 0.936 – 0.996 |

Jump height = Means ± SD; ICC = Intra-class Correlation; CI = Confidence Interval;
 * = Acceptable Reliability

3.5.2. 20-meter Sprint Test

The ability to sprint and get to the ball first in team sports is a fundamental component necessary for success. This component of fitness is often evaluated to show athletic ability and training status (Hopker et al., 2009). Subjects attended three testing days, all were performed outdoor on an all-weather surface. During each of the testing sessions, subjects performed three maximal effort 20-meter sprints from a standing start (Rumpf et al. 2011). The 20-meter path had a start timing gate, a 10-meters split timing gate and

a finish timing gate at the 20-meter mark using a photocell speed gate system (Beam Trainer, Domago, Slovenia). Timing gates were set up at a height of 80cm above ground level. (see **Figure 8**).



Figure 8: The 20-meter Sprint Test.

Results

Table 5: Intra-class correlations of the 20-meter sprint test

| Test: 20-meter Sprint | Time (secs) ± SD | ICC Value | 95% CI |
|-----------------------|------------------|-----------|---------------|
| 10 Meter (Split) | 1.93 ± 0.11 | 0.962* | 0.861 – 0.992 |
| 20 Meter Sprint | 3.42 ± 0.26 | 0.910* | 0.696 – 0.980 |

Time = Means ± SD; ICC = Intra-class Correlation; CI = Confidence Interval;

* = Acceptable Reliability

3.5.3. The Y-Balance Test

The y-balance test is an assessment that will examine a person’s strength, flexibility and balance and has been used to both evaluate physical performance, and potentially uncover athletes that are at risk for lower limb injuries (Plisky et al. 2009). During the test, each subject performed a single leg balance test on both the right and left leg while

standing on a central foot platform. Three PVC tubes are attached to the central foot platform in the anterior, posteromedial and posterolateral directions. The subject stands on one leg on the central foot platform and pushes a reach indicator with the other foot along one of the tubes in the direction of the test (see **Figure 9**). The reach distances were noted, and average distance recorded for each subject, following three trials in each of the three directions on both legs. Because reach distance is associated to limb length, each participant reach distance was normalised to limb length to allow results to be compared to other studies. To express reach distance as a percentage of their limb length (Plisky et al. 2009), the following formula was used;

Mean Reach distance/limb length x 100 = Normalised Mean Reach %.



Figure 9: The Y-Balance test.

Results

Table 6: Intra-class correlations of the Y-Balance test

| Test: Y-Balance | | Average Reach | | | Normalised Reach | | |
|-----------------|-------|-----------------|-----------|---------------|------------------|-----------|---------------|
| | | Reach (cm) ± SD | ICC Value | 95% CI | Reach (cm) ± SD | ICC Value | 95% CI |
| Anterior | Right | 65.88 ± 8.64 | 0.926* | 0.762 – 0.984 | 65.94 ± 7.45 | 0.897* | 0.670 – 0.977 |
| | Left | 66.54 ± 9.20 | 0.873* | 0.581 – 0.972 | 66.66 ± 8.57 | 0.846* | 0.487 – 0.966 |
| Posteromedial | Right | 102.38 ± 6.46 | 0.862* | 0.532 – 0.970 | 103.12 ± 5.13 | 0.942* | 0.813 – 0.987 |
| | Left | 101.88 ± 6.58 | 0.916* | 0.731 – 0.981 | 102.11 ± 6.23 | 0.906* | 0.700 – 0.979 |
| Posterolateral | Right | 97.29 ± 6,13 | 0.963* | 0.875 – 0.992 | 97.50 ± 5.43 | 0.949* | 0.829 – 0.989 |
| | Left | 99.96 ± 6.29 | 0.976* | 0.923 – 0.995 | 89.66 ± 5.24 | 0.943* | 0.815 – 0.987 |

ICC = Intra-class Correlation; CI = Confidence Interval; * = Acceptable Reliability

3.6. Discussion

Reliability in sports performance testing refers to the reproducibility of the results of a particular test during repeated trials on the same subject. Reliability is a means of evaluating the quality of the measurement system used to collect data in a study, with better reliability scores inferring better accuracy of single measurements (Hopkins, 2000). According to Hayen et al., (2007), ICC values can range from 0 to 1, with values close to 0 caused by a result of measurement error, and close to 1 demonstrating excellent reliability. Dupuy et al., (2012) further classified ICC values when stating, values above 0.90 as having very high reliability, between 0.70 and 0.89 as high reliability, and moderate reliability when it ranged from 0.50 to 0.69. Any ICC values below 0.50 were considered as not being reliable. Results obtained in the current study ranged from high reliability in the y-balance assessment (ICC 0.846) to very high reliability in the CMJ (ICC 0.980).

The ICC of the CMJ (see **Table 4**) in this study displayed a very high intra-rater reliability with a value of 0.980. These results are consistent with a previous investigation of three different counter movement jumps which established an ICC value of 0.930 (95% CI: 0.85 – 0.96) (Slind et al. 2008). Similarly, while investigating the reliability of the squat and CMJ, Markovic et al. (2004) established the CMJ as having an excellent reliability with an ICC value of 0.98 recorded.

Like the CMJ, very high ICC values were obtained for the 20-meter sprint test and the 10-meter split phase, showing ICC values of 0.910 and 0.962 respectively (see **Table 5**). These results are comparable to previous investigations associated with the reliability of performance assessments in sprint testing, with one youth athlete study establishing ICCs ranging from 0.88 to 0.98 (Rumpf et al., 2011). Additionally Gabbett et al., (2008) examined the test-retest reliability of 10-meter and 20-meter sprint and confirmed reliable results with ICC values ranging from 0.84 – 0.96.

The y-balance test recorded ICC values ranging from 0.846 to 0.976 (see **Table 6**). These results are consistent with an investigation by Plisky et al., (2009) who reported ICC values for normalised data ranging from 0.85 to 0.88. Likewise, average reach distances in a study involving multiple raters revealed an ICC ranging from 0.85 to 0.93 (Shaffer et al. 2013).

In conclusion, the current study has demonstrated high to very high reliability for the CMJ, 20-meter sprint and y-balance performance tests. The protocols and methodologies used in the reliability study for the neuromuscular performance tests will be applied in the principle part of this investigation.

Chapter 4: Methodology

4.1. Introduction

This analytical observation cohort study was conducted to establish the effectiveness of the GAA15 (injury prevention programme) in reducing injuries in adolescent males playing hurling at post primary school and club level during one season. Comparisons were made to a gender and aged matched control group whose subjects participated in normal pre-training and pre-match warm-up methods. Training and match exposure time (mins) along with injury incidence were recorded throughout the investigation period by a player self-reported mobile application. Baseline neuromuscular measures for each participant were assessed at the start of the investigation period and again at the end of their season to evaluate any physical effects that may have transpired. Any trends that were noted were critically analysed to investigate if there was a relationship between the intervention programme and the functional post trial retest. Ethical clearance was granted by the Research Ethics Committee at the Institute of Technology Carlow on September 30th., 2015 (see **Appendix B**).

4.2. Aims

- To evaluate the effectiveness of the GAA15 injury prevention programme in reducing injuries in adolescent males participating in hurling.
- To compare pre to post season neuromuscular performance assessment results, within each of the groups.
- Establish injury epidemiology data via a self-reporting mobile phone web application.

4.3. Participants

School participants ($n = 516$) were recruited from fourteen post primary schools from two Irish provinces Leinster and Munster. Post primary schools were selected and contacted based on their geographical convenience to the centre of research, the

Institute of Technology Carlow. Post primary schools were emailed by the lead researcher, which included details of the research investigation and an invitation to participate. Senior (under 18.5 years) and juvenile (under 14.5 years) school hurling teams were enlisted to participate in the investigation. Club players ($n = 305$) were recruited from six GAA club teams from three different age groups, under 14, under 16 and under 18 years (see **Figure 10**). GAA clubs were contacted through a phone call from the lead researcher, details of the research investigation were explained and an invitation to participate was extended to the club.

The allocation procedure to intervention and control groups for this investigation was based on school and club team geographical proximity to the centre of research, the Institute of Technology Carlow. Intervention group teams were located within 35km from the centre of research with control group teams outside of this distance. Written consent and, or, assent where appropriate, was obtained from the participants and parents/guardians (see **Appendix A**). Parents/guardians, coaches and participants were informed, through an information gathering, on the details, purpose, benefits and testing procedures of the research investigation and to the prerequisites if they agreed to participate. Participants were told they were not obliged to partake and that departure from the research study at any stage of the investigation was allowed without consequence to their hurling participation or team selection. School and club teams, players and coaches took part in the research study with no remuneration from the Institute of Technology Carlow or the GAA.

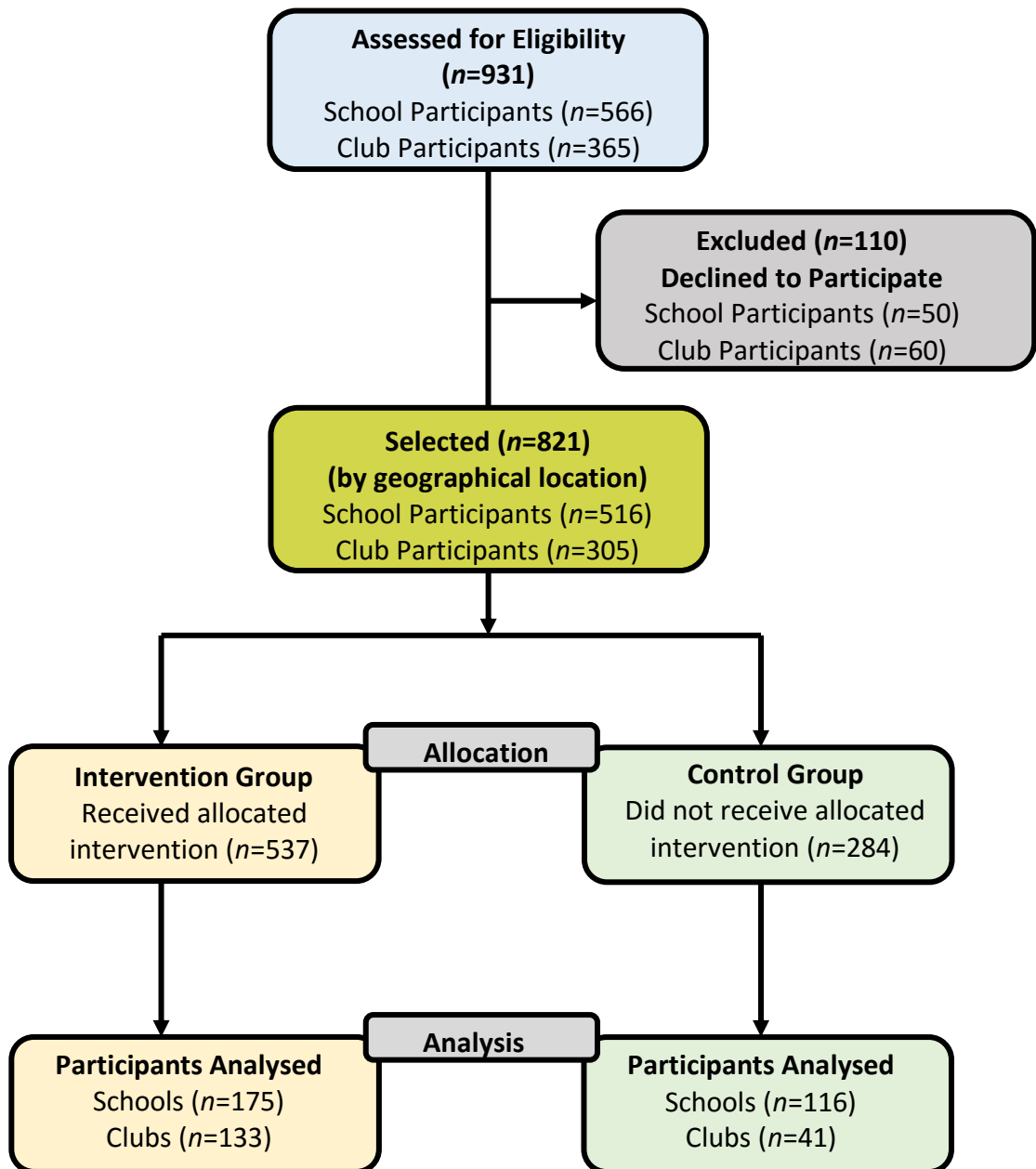


Figure 10: Participant enrolment details.

4.3.1. Participant Inclusion Criteria

To be included in the research study, participants had to be:

1. Male and between the ages of 13 and 18.5 years at the time of recruitment.
2. Participating in post primary school hurling at juvenile (under 14.5 years) or senior (under 18.5 years) level.
3. Participating in club hurling at under 14, under 16 or under 18 years.

4. Be free from injury to enable them to participate in baseline neuromuscular performance testing, hurling training and matches.
5. Be able to access and use mobile phone web application.
6. Parental consent (<18yrs) and participant assent (>18yrs) attained.

4.3.2. Participant Exclusion Criteria

1. Any participant with an injury preventing them from taking part in hurling training, matches or baseline neuromuscular performance testing.
2. Parental consent not presented before neuromuscular assessment or start of investigation period.

4.4. Research Design

An analytical observation cohort study was used. This investigation consisted of four parts, (1) Neuromuscular performance assessment, (2) The selected GAA15 intervention programme, (3) Epidemiological data collection, and (4) Qualitative analysis (see **Figure 11**).

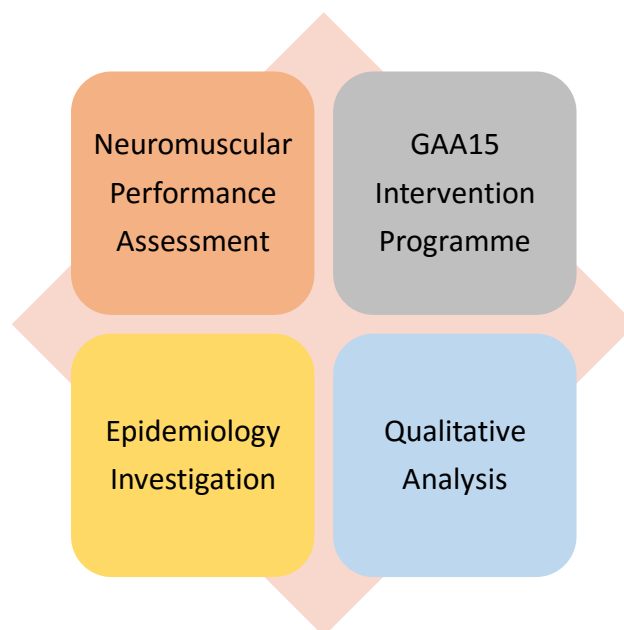


Figure 11: Sections of current research investigation

Prior to commencement of the research, each participant underwent a screening process, by the lead researcher, to provide a baseline neuromuscular function and physical performance measurement (see **Table 7**). Testing was completed in venues at each of the participating schools and GAA clubs. The same tests were completed a second time, by the lead researcher, at the end of the experimental period, which was the whole duration of their competitive playing season or when their respective teams exited their hurling competitions, whichever happened first. A typical post primary school hurling season can be expected to last between four to six months depending on how successful the teams are, with club hurling seasons normally lasting between four to eight months.

Table 7: Neuromuscular physical performance tests.

| Name of Test | Unit of Measurement | Measure |
|--------------------------|------------------------|--|
| 1. 20-meter Speed | Time (Seconds) | Acceleration and maximum linear running speed. |
| 2. Counter Movement Jump | Height (Centimetres) | Lower body leg power. |
| 3. Y-Balance Test | Distance (Centimetres) | Single leg strength, flexibility and balance. |

School and club team hurling managers, coaches and trainers, were briefed and educated on the purpose of the study with supporting data through a workshop format prior to data collection commencing. The intervention group participants were instructed on the components of the GAA15 intervention programme and how to integrate it into their pre-match routine and before every hurling training session. Managers and coaches of the participating intervention group teams received a DVD of the selected GAA15 neuromuscular warm-up programme along with a printed copy of the programme structure, layout and routine (see **Appendix C**). The teams in the control group utilised their normal warm-up routine before hurling training and matches during the investigation period.

For the qualitative analysis, semi-structured interviews were carried out with intervention team trainers/coaches and one random player from each team to get a

better understanding into the implementation and usage of the GAA15 intervention programme.

4.5. Injury Definition

An injury was defined as “any injury sustained during hurling training or competition resulting in time lost from play or athlete reported restricted performance” (Brooks 2005; Murphy et al. 2012; O’ Connor et al. 2016). Any previously injured player who was able to fully take part in hurling training and was available for match selection was deemed to have returned to sport (Brooks et al. 2005; Murphy et al. 2012). A recurrent injury was defined as “any injury of the same type and site of the original injury that occurred after the athlete returned to full participation” (Fuller 2006; O’ Connor et al. 2016).

Before the commencement of data collection, participants and team coaches were educated on the definition of injury through an information workshop. Adolescent participants were informed that if they sustained an injury, and subsequent to receiving this injury could not continue training or playing a match, this was defined as an injury and had to be reported through their mobile phone web application. Participants were advised, if they return to play following a reported injury and re-injure the same body part during the same hurling season (research period), this was to be reported as a recurrent injury. Participants were instructed to point to the area and side of the body where they sustained the injury on their mobile phone web application (see **Figure 12**).

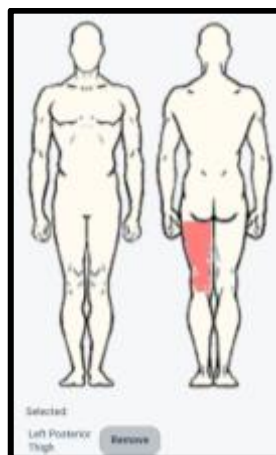


Figure 12: Smartabase web application – participant self-report injury.

4.6. Epidemiological Data Collection

Epidemiological data was collected (see **Figure 13**) from a participant self-report mobile phone web application (Smartabase Athlete Data Management, Fusion Sport, Summer Park, QLD, Australia). Participants entered information daily, including the number of hurling training sessions and matches along with the playing activity duration (mins), and the rate of perceived exertion (RPE) of the activity.

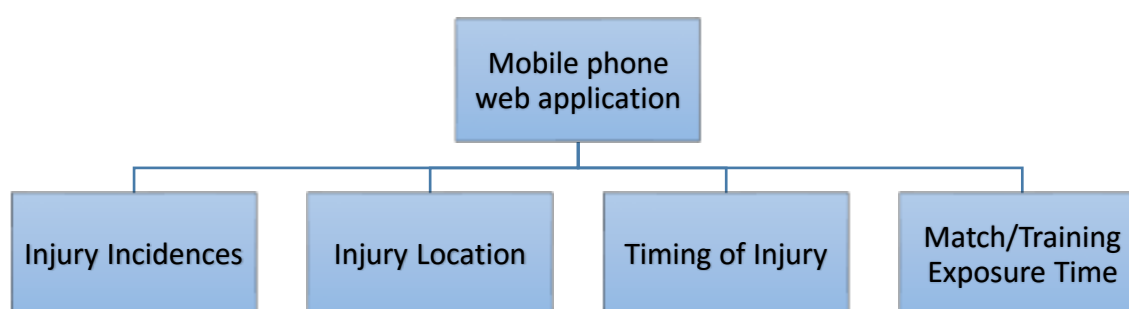


Figure 13: Epidemiological data collected from mobile phone web application.

Data was collected and split into two groups, intervention and control. Prior to the commencement of the study, the lead researcher conducted a workshop training day for each of the participating teams involved, where the subjects, coaches and parents were educated on the setup and use of the mobile phone web application. Players were provided with usernames and passwords and uploaded the web application during the workshop. If adolescent players didn't have smartphones, desktop PC's, laptops or parent's mobile phones could be used to access the Smartabase system. All participating players received a text message from the Smartabase online system four times every week to remind them to submit their wellness details. From the information collected, participant training units were calculated by multiplying the duration of a training session or match (mins) by the participants individual RPE for that particular activity (see **Figure 14**).

Training Units = Total activity time (mins) x Rate of perceived exertion (RPE number)

Participants reported their injury details following hurling training or match activity during the investigation period (see **Figure 15**). From this information injury rates (IR) per 1000 hours of activity, with respective 95% confidence intervals (CI) were determined. Risk ratios (RR) and 95% CI were used to compare injury rates (Murphy et al. 2012). Injury incidence refers to the number of new injury occurrences during a specified period of time, in this case a playing season (Knowles et al. 2006).

Injury Incidence = Number of new injuries during the research period (playing season).

The figure displays three screenshots of the Smartabase web application interface. The first screenshot, titled 'Training Details 1', shows two sections: 'Daily Activity 1' with radio button options for Match, Training, Gym, and None; and 'What Sport? 1' with radio button options for Hurling, Gaelic Football, Soccer, Rugby, and Other. The second screenshot, titled 'Difficulty (RPE) 1', shows a vertical list of radio button options from 0 (Rest) to 10 (Maximal), with descriptive labels for levels 1 through 9. The third screenshot, titled 'Duration (mins) 1', shows a vertical list of radio button options for durations from 0 to 120+ minutes in increments of 10.

Figure 14: Smartabase web application – training and match exposure time.

Injury rates (IR) per 1000 hours, injury incidence proportion (IP) and repeat injury incidence proportion was calculated using the following methods (Knowles et al. 2006; O’ Connor et al. 2016).

IR was defined as the number of new injuries divided by the total exposure time (hours) of participant activity during the research period, using the subsequent calculation (Knowles et al. 2006).

Injury Rate (IR) = Number of new injuries ÷ Athlete exposure time (hours) x 1000

95% Confidence Interval (CI) = IR ± 1.96 x SE(IR)

Standard Error (SE) = $\sqrt{\text{Number of Injuries} \div \text{Total hours playing sport}}$

Incidence proportion (IP) measures the risk of injury where the number of injured participants are divided by the total number of participants at risk during a period of time, in this case, during one competitive season. The IP can be interpreted as the probability, across all participants, that one participant will be injured during the research period. The subsequent calculation was used to determine the research IP (Knowles et al. 2006).

Incidence Proportion (IP) = $\frac{\text{Number of injured participants during research period}^*}{\text{Number of participants at risk during research period}}$

95% Confidence Interval (CI) = IR ± 1.96 x SE(IP)

Standard Error (SE) = $\sqrt{IP \times (1 - IP) \div N^{**}}$

*Participants who sustain at least one injury.

** Total number of participants at risk during research period (one season).

IP only measures the risk of participants who were injured once, therefore repeat incidence proportion measures the risk to participants who were injured multiple times during the season. The subsequent calculation was used to determine the repeat IP (O' Connor et al. 2016).

Repeat Incidence Proportion = $\frac{\text{Number of repeat injured participants during research period}}{\text{Number of injured participants during research period}}$

Lastly, to quantify the difference in injury rates between the two research groups, the intervention group IR was divided by the control group IR to get the injury rate ratio (IRR) (Knowles et al. 2006).

Injury Rate Ratio (IRR) = $\frac{\text{Intervention Group IR}}{\text{Control Group IR}}$

The frequency of injury to particular body locations and the registered date of injury during the investigation playing season was also recorded and analysed by the lead researcher.

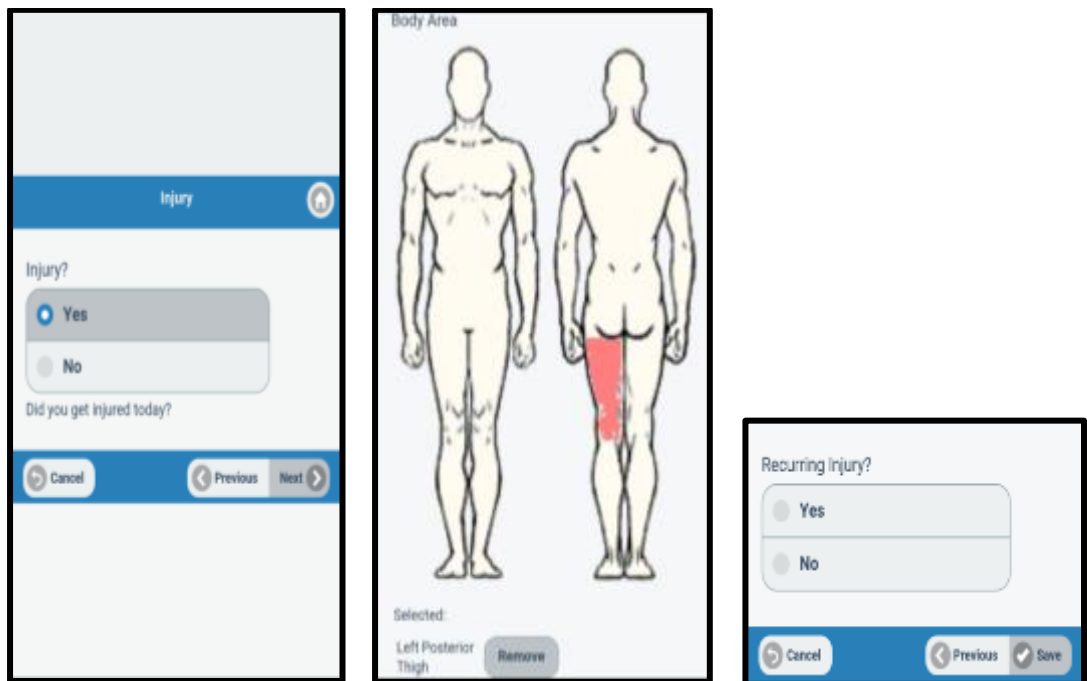


Figure 15: Smartabase web application – injury incidence details.

4.7. Neuromuscular Performance Assessment

Before the start of the intervention period, each participant took part in a neuromuscular function and physical performance assessment which consisted of a 20-meter sprint, counter movement jump and a Y-balance test. Before the start of assessment, participants took part in a 6 to 8-minute dynamic warm-up (see **Appendix D**) before any testing commenced. Participants were randomly assigned to one of three groups (Group 1 = 20-meter sprint; Group 2 = counter movement jump; Group 3 = Y-balance test), with all tests running concurrently. Each group had a five-minute recovery period at the end of one test before beginning the next test. The order of testing was completely random, to prevent one test influencing the result of the subsequent test.

4.7.1. Apparatus used for Neuromuscular Assessment

- Participants height (cm), weight (kg) and leg length were obtained using SECA 217 Stadiometer, SECA Robusta 813 Digital Scales and Seca plastic measuring tape respectively (Hammer Steindamm, Hamburg, Germany).
- Counter movement jump was conducted using a contact mat (Just Jump, Probotics Inc., Esslinger Court, Huntsville, Ala.).
- The linear speed assessment used a photocell speed gate system (Beam Trainer, Domago, Slovenia).
- The Y-Balance test (Functionalmovement.com) was used to assess single leg dynamic balance, flexibility and strength.

4.7.2. Counter Movement Jump

Counter movement jump (CMJ), without the use of arm swing (hands placed on hips), or encouragement, was used for this assessment. The lead researcher provided a demonstration to the participants of how to jump and then allowed each subject to practice the jump until jumping technique was satisfactory, which usually took three jumps. Each test jump commenced with the subject stepping onto the contact mat and starting from a standing position with feet and legs vertically aligned and hands placed on hips (see **Figure 16**). On command, the CMJ was performed, the subject flexed knees to approximately 90° and squatted down in advance of a quick extension of the legs and take off before landing on the contact mat. After initial extension of the knees, subjects' legs remained straight until landing on the mat. If any of the jump specifications were not met, the subject was required to jump again. The jump mat provided data for the subjects time in the air, from which the maximum jump height was calculated using the following equation of uniform acceleration: $\frac{1}{2}g(t/2)^2$, where $g = 9.81\text{m/s}^2$ and $t =$ time in the air (seconds) (Moir et al. 2008). Each subject completed three jumps using correct technique while wearing sports footwear.



Figure 16: Counter Movement Jump (CMJ)

4.7.3. 20-meter Sprint Test

Testing took place indoors, free from obstruction and with adequate space for deceleration following the 20-meter sprint (see **Figure 17**). The testing protocol consisted of each subject running three maximal sprint efforts, starting from a standing position, separated by at least 3 minutes of passive recovery between each sprint.



Figure 17: The 20-meter sprint test.

The 20-meter course had a timing start gate, a timing split at 10-meters and a finish timing gate at the 20-meter mark using a photocell speed gate system positioned at a height of 80cm above ground level. Each subject was instructed to start from a line 1-meter behind the first timing gate and begin from a static standing position (Walker & Turner 2009).

4.7.4. Y-Balance Test

The Y-balance test (see **Figure 18**) was carried out on an instrument for measuring single leg dynamic balance, flexibility and strength (Plisky et al. 2009). For familiarisation, each subject practiced three trials on each leg in each of the three directions before formal testing commenced. No sports shoes were worn during testing. Subjects stood on one leg, with their foot behind the starting line on the centre block of the testing device (Y-Balance Test Kit, www.functionalmovement.com).

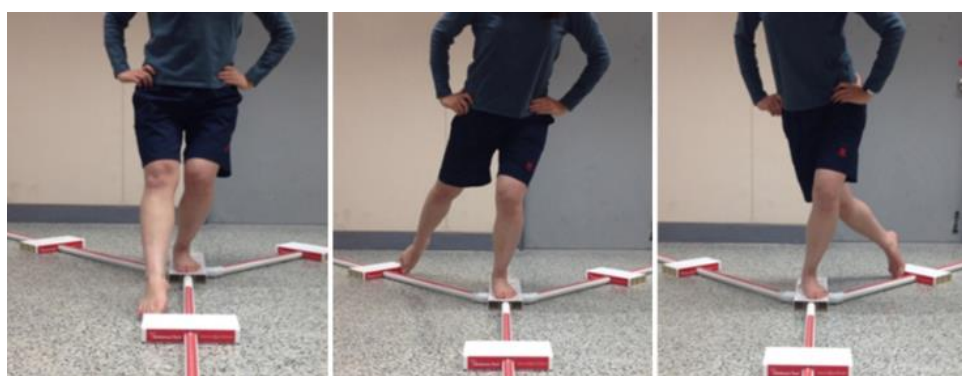


Figure 18: The Y-Balance test.

While balancing on one leg, the subject was instructed to reach with the other foot in three directions, anterior, posteromedial and posterolateral while pushing a marker as far as possible without losing balance. Each subject completed three trials on each leg in each of the three directions. The maximal and average reach distance was recorded for each of the three directions for the right and left legs. The order of testing was anterior (right and left leg respectively), posteromedial (right and left leg respectively) and posterolateral (right and left leg respectively). Reach distances were recorded to the nearest 0.5cm. Participants reach distances were normalised to their leg lengths, with leg measurements (Seca plastic measuring tape) taken from the anterior superior iliac spine (ASIS) to the distal medial malleolus (Plisky et al. 2009). This normalised score was calculated by dividing the reach distance by the participants' leg length and then multiplying by 100.

$$\text{Normalised Y-Balance Score} = \text{Reach distance (cm)} \div \text{Leg length (cm)} \times 100$$

Participant composite scores were acquired by the addition of the three scores for the three directions, and the result divided by three times the leg length and then multiplied by 100 (Plisky et al. 2009).

$$\text{Composite Score} = \text{Anterior} + \text{posteromedial} + \text{posterolateral (cm)} \div 3(\text{leg length}) \times 100$$

The Y-balance test score was rejected, with the participant asked to repeat the test if:

- (a) the reach foot of the participant touched the floor or if they lost balance and fell off the testing device,
- (b) kicked the reach marker rather than maintaining contact while performing the test,
- (c) placed their foot on top of the reach marker for support while reaching,
- (d) were unable to return to the starting position while under control (without losing balance) (Plisky et al. 2009).

4.8. Statistical Analysis

Statistical analysis of data was performed using IBM SPSS (Statistical Package for Social Sciences, version 22.0). Baseline characteristics, measured as continuous variables, were displayed as mean plus standard deviation (SD) and categorical variables such as number of injuries were expressed as percentages (Owoeye et al. 2014). A Shapiro Wilks tests was used on the complete data set to investigate for normality of data. Paired T-tests were used to analyse the neuromuscular performance test data for pre-test and post-test assessment results in the intervention and control groups.

Injury data was examined by calculating percentages and injury rates per 1000hrs with 95% confidence intervals (CIs). Incidence proportions (IPs) and risk ratios (RRs) were used to compare injuries and were calculated using VRP Injury Statistics Software, by Conor Gissane 2007.

4.9. The GAA 15 Intervention Programme

The intervention warm-up programme for this investigation (see **Table 8**) was the GAA15 injury prevention programme. The GAA15 warm-up programme took between 12 to 15 minutes to complete and consisted of three different phases, which were performed in a specified sequence at the beginning of each hurling training session and match. The warm-up programme was completed on grass playing fields at post primary school and GAA club venues.

Table 8: GAA15 intervention programme (see Appendix C for more detail).

| Section | Exercise Target |
|---------|---|
| Phase 1 | Raising the participants body temperature. Running exercises. |
| Phase 2 | Improving movement mechanics and limiting the risk of injury. Dynamic movements, mobility, stretching, agility, plyometrics, proprioception and strength. |
| Phase 3 | Flexibility, sport specific movement speed. |

4.10. The Control Group

Participants allocated to the control group employed their normal warm-up routine before all training sessions and matches throughout the investigation period. No information was collected on the structure or content of these warm-ups.

4.11. Qualitative Analysis

The final part of this investigation comprised of qualitative methodologies which consisted of semi-structured interviews to gain a deeper understanding into the practical implementations of this injury prevention strategy. Semi-structured interviews were conducted with team coaches and trainers to provide further comprehension into injury prevention support structures and with one participant from each team to gain a

deeper awareness of recipients views with respect to the warm-up practicalities, timing, compliance and reception to the programme.

Participants

Fourteen interviews were conducted by the lead researcher with team coaches and players at the end of the research period who had used the GAA15 intervention programme. Six interviews were carried out with team coaches and eight interviews with team players from different age groups. The players were randomly selected by the team coaches.

Semi-structured Interviews

Interviews were carried out at post primary schools and GAA clubs by pre-arranged schedules convenient to team coaches, managers and participants. Before the commencement of interviews, each participant was encouraged to be honest with their overall assessment of the research and the answers to the questions raised and not to be influenced by the presence of the lead researcher. Interviewees were asked nine questions each, with two questions structured differently for coaches and participants respectively (see **Appendix E**). Interview questions were structured to get a greater understanding of coaches and players perception of injury prevention warm-up programmes and on the implementation of the chosen programme used in this investigation. All interviews were recorded with interviewees made aware of this before commencement.

Analysis

Interviews were recorded (Samsung voice recorder) by the lead researcher and manually transcribed to Microsoft word documents. Common themes were developed based on the information provided and a simple content analysis was performed.

Chapter 5: Results

5.1 Quantitative Results

5.1.1 Participants

A total of 821 participants were recruited from fourteen post primary schools and six GAA clubs throughout the Leinster and Munster regions. Post primary school participants ($n=516$) were selected from teams at two different age grades, senior (under 18.5 years) and juvenile (under 14.5 years). Club participants ($n=305$) were selected from three age grades, under 18, under 16 and under 14 years. Participants from school and club hurling teams were allocated to either intervention ($n=537$) or control ($n=284$) groups based on the geographical location of their school or club. Due to the numerous school/team locations, it was difficult for the lead researcher to get equal numbers set up in both groups. After subject dropout, final analysis consisted of 308 intervention (school $n=175$, club $n=133$) and 157 control (school $n=116$, club $n=41$) participants (56.6%). Due to the inconsistency of participant numbers reporting during the research period, the percentages were calculated out of the available totals.

5.1.2. Anthropometric Measures

A total of 821 players participated in the investigation with the anthropometric measurements for all displayed in **Table 9**.

Table 9: Total ($n=821$) Participant Mean Characteristics and Anthropometrics.

| Characteristic | Mean \pm SD |
|-----------------------|-----------------|
| Age (Years) | 15.9 \pm 1.9 |
| Height (Centimetres) | 177.4 \pm 6.9 |
| Weight (Kilograms) | 71.7 \pm 9.5 |
| BMI (Body Mass Index) | 22.6 \pm 3.1 |

5.1.3. Data Collection

Post primary school data collection took place during the 2015/2016 hurling season, between September 2015 and April 2016. Club hurling data collection was carried out during the 2016 hurling season (April to October 2016).

5.1.4. Injury Incidence

An injury was defined as “any injury sustained during hurling training or competitive match resulting in time lost from play or reported restricted performance” (Brooks 2005; Murphy et al. 2012; O’ Connor et al. 2016).

In total 227 hurling injuries were recorded during the investigation period, giving a total injury incidence (IR) rate of 21.53 (95% CI 18.8-24.3) injuries per 1000 hours of participation (see **Table 10**). Confidence intervals (95% CI) are a range of values calculated by statistical means which offer evidence about where the true value lies with a definite degree of probability (du Prel et al. 2009). The total hurling training IR was 17.39/1000h (95% CI 14.0-20.8), which was less than half the IR for competitive matches (42.61/1000h, 95% CI 35.1-50.1). Independently, school (training 16.21/1000h, 95% CI 12.3-20.1; match 39.61/1000h, 95% CI 30.6-48.6) and club (training 20.8/1000h, 95% CI 13.5-26.6; match 48.35/1000h, 95% CI 34.7-62.0) injury rates exhibited similar patterns, with match injury rates more than twice the amount for training.

Table 10: Hurling Injury Incidence Rate (IR)

| Injuries per 1000 hrs | n of inj. | <u>Combined</u> | | n of inj. | <u>School</u> | | n of inj. | <u>Club</u> | |
|---|--------------|-----------------|-----------|--------------|---------------|-----------|--------------|-------------|-----------|
| | | IR | 95% CI | | IR | 95% CI | | IR | 95% CI |
| Total Injury Incidence Rate for Hurling | | | | | | | | | |
| Total | 227 | 21.53 | 18.8-24.3 | 145 | 20.63 | 17.3-23.9 | 82 | 23.29 | 18.4-28.2 |
| Training | 103 | 17.39 | 14.0-20.8 | 67 | 16.21 | 12.3-20.1 | 36 | 20.08 | 13.5-26.6 |
| Match | 124 | 42.61 | 35.1-50.1 | 76 | 39.61 | 30.6-48.6 | 48 | 48.35 | 34.7-62.0 |
| Lower Extremity Incidence Rate for Hurling | | | | | | | | | |
| Total | 151 | 14.75 | 12.5-17.0 | 96 | 13.99 | 11.3-16.7 | 55 | 16.25 | 12.1-20.4 |
| Training | 65 | 12.10 | 9.3-14.9 | 43 | 11.29 | 8.0-14.6 | 22 | 13.94 | 8.5-19.4 |
| Match | 86 | 31.18 | 24.7-37.6 | 53 | 29.04 | 21.4-36.7 | 33 | 35.25 | 23.6-46.9 |

Injuries to the lower extremity were most common during the research period with 151 injuries from a total of 227 injuries received. The total lower extremity IR (see **Table 10**) for all participants was 14.75/1000h (95% CI 12.5-17.0). Lower extremity match injury rates were more than 2.5 times higher than training injuries in school (match 29.04/1000h, 95% CI 21.4-36.7; training 11.29/1000h, 95% CI 8.0-14.6) and club (match 35.25/1000h, 95% CI 23.6-46.9; training 13.94/1000h, 95% CI 8.5-19.4) hurling participants. Lower extremity school hurling injury rates were lower than club rates, for training (school : club; 11.29 : 13.94/1000h) and competitive matches (school : club; 29.04 : 35.25/1000h) respectively.

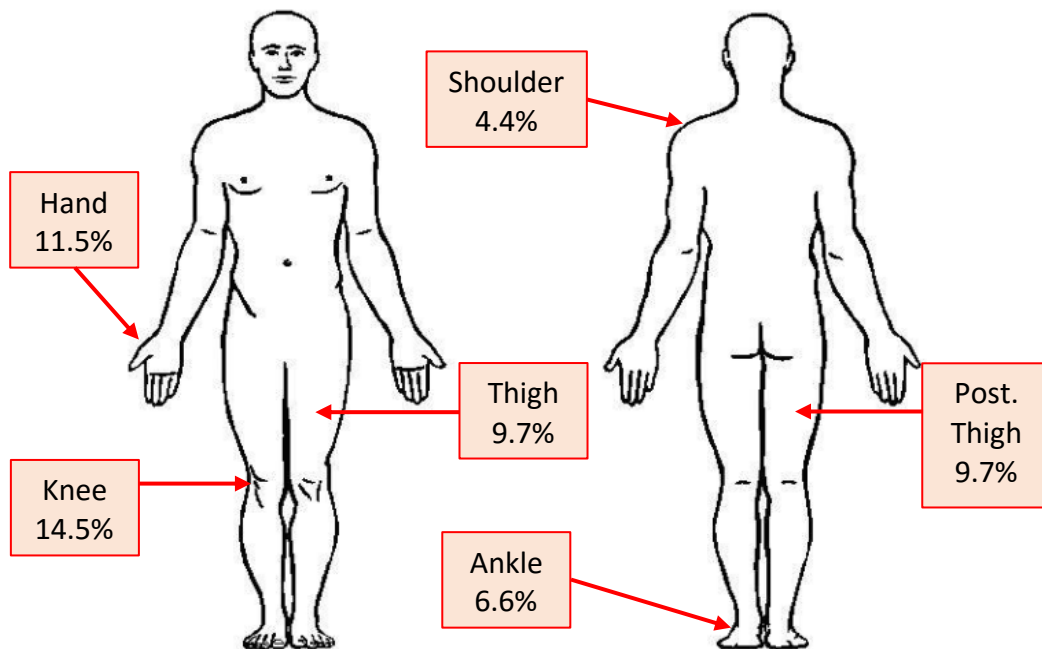


Figure 19: Regional distribution of most frequently injured body parts.

5.1.5. Most frequently injured body part

Injury distribution and region of injury are displayed in **Table 11**. The lower extremity was the most frequently injured body region with 66.5% of all injuries reported. The upper extremity was the next most injured body region with 26.9% of injuries (61 incidences) with the head, neck and spine the least injured region with 6.6% of injuries (15 incidences) reported. The knee (33 incidences) was the most frequently injured part

of the body with 14.5% of the total number of injuries recorded, the posterior and anterior thigh (22 incidences, 9.7%) were the next most injured body locations reported (see **Figure 19 and 20**). The hand was the most injured upper body part with 11.5% (26 incidences), alongside the shoulder region which accounted for 4.4% (10 incidences) of all upper extremity injuries. There were six injuries (2.6%) recorded to the lumbar spine and head region. The least injured region of the lower extremity was the buttock and pelvis region with 3 incidences (1.3%) recorded. The forearm, upper arm and posterior shoulder were the least injured upper extremity body regions injured with 2 injuries (0.9%) each.

Table 11: Total (n=227) Hurling Injury Details

| INJURY SITE | NUMBER of INJURIES | % TOTAL | SCHOOL | | CLUB | |
|---------------------------------|--------------------|-------------|--------------|--------------------|--------------|--------------------|
| | | | IR | CI | IR | CI |
| LOWER EXTREMITY INJURIES | 151 | 66.5 | 13.71 | 11.01-16.41 | 14.08 | 10.26-17.91 |
| Ankle | 10 | 4.4 | 0.83 | 0.20-1.50 | 1.08 | 0.02-2.15 |
| Buttock & Pelvis | 3 | 1.3 | 0.28 | 0.00-0.66 | 0.27 | 0.00-0.80 |
| Foot | 9 | 4.0 | 0.55 | 0.01-1.10 | 1.35 | 0.17-2.54 |
| Post. Thigh | 22 | 9.7 | 1.66 | 0.72-2.60 | 1.35 | 0.17-2.54 |
| Hip & Groin | 17 | 7.5 | 2.91 | 1.66-4.15 | 3.25 | 1.41-5.09 |
| Knee | 33 | 14.5 | 0.28 | 0.00-0.66 | 1.08 | 0.02-2.15 |
| Post. Foot | 6 | 2.6 | 2.08 | 1.03-3.13 | 0.81 | 0.00-1.73 |
| Post. Lower Leg | 18 | 7.9 | 2.63 | 1.45-3.81 | 0.81 | 0.00-1.73 |
| Thigh | 22 | 9.7 | 2.22 | 1.13-3.30 | 1.63 | 0.32-2.93 |
| Lower Leg | 6 | 2.6 | 0.14 | 0.00-0.41 | 1.35 | 0.17-2.54 |
| Post. Ankle | 5 | 2.2 | 0.14 | 0.00-0.41 | 1.08 | 0.02-2.15 |
| UPPER EXTREMITY INJURIES | 61 | 26.9 | 4.85 | 3.24-6.45 | 7.04 | 4.34-9.75 |
| Hand | 26 | 11.5 | 1.66 | 0.72-2.60 | 3.79 | 1.81-5.78 |
| Wrist | 3 | 1.3 | 0.14 | 0.00-0.41 | 0.54 | 0.00-1.29 |
| Side | 4 | 1.8 | 0.42 | 0.00-0.89 | 0.27 | 0.00-0.80 |
| Forearm | 2 | 0.9 | 0.14 | 0.00-0.41 | 0.27 | 0.00-0.80 |
| Post. Hand | 3 | 1.3 | 0.42 | 0.00-0.89 | | |
| Shoulder | 8 | 3.5 | 0.83 | 0.20-1.5 | 0.54 | 0.00-1.29 |
| Upper Arm | 2 | 0.9 | 0.28 | 0.00-0.66 | | |
| Post. Shoulder | 2 | 0.9 | 0.28 | 0.00-0.66 | 0.27 | 0.00-0.80 |
| Chest | 5 | 2.2 | 0.14 | 0.00-0.41 | 0.27 | 0.00-0.80 |
| Elbow | 6 | 2.6 | 0.55 | 0.01-1.10 | 1.08 | 0.02-2.15 |
| HEAD, NECK & SPINE | 15 | 6.6 | 1.52 | 0.62-2.42 | 1.08 | 0.02-2.15 |
| Lumbar Spine | 6 | 2.6 | 0.69 | 0.09-1.30 | 0.27 | 0.00 |
| Head | 4 | 1.8 | 0.28 | 0.00-0.66 | 0.54 | 0.00 |
| Post. Head | 2 | 0.9 | 0.28 | 0.00-0.66 | | |
| Neck | 1 | 0.4 | | | 0.27 | 0.00 |
| Thoracic Spine | 2 | 0.9 | 0.28 | 0.00-0.66 | | |

IR = Incidence Rate, CI = Confidence Interval.

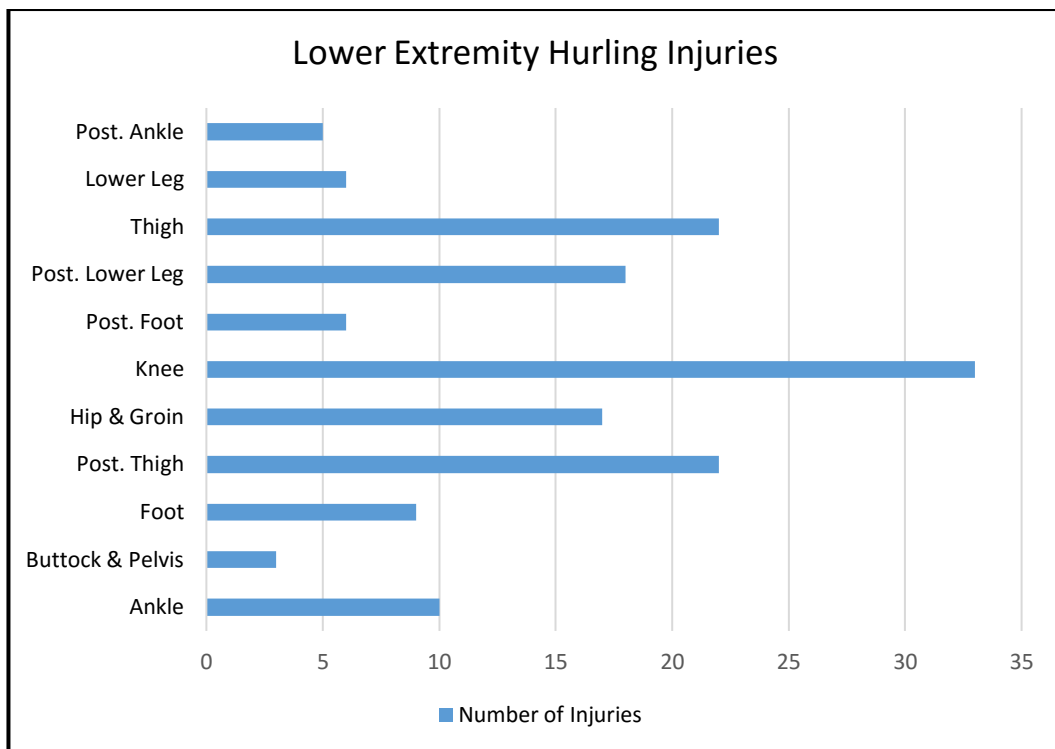


Figure 20: Frequency of lower extremity hurling injuries

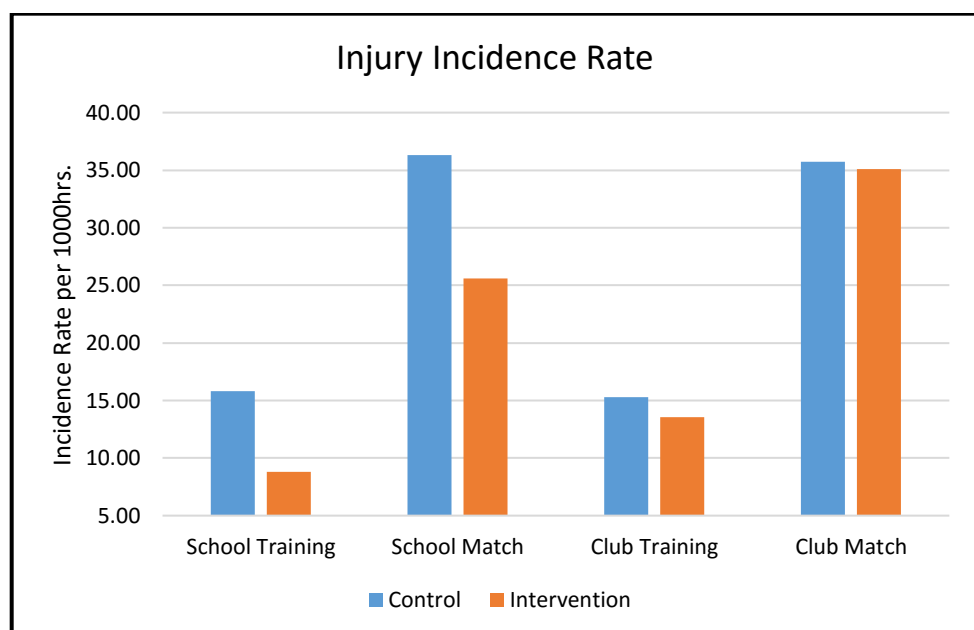
5.1.6. Injury Incidence (Control versus Intervention)

Injury incidence rates for the control ($n=157$ players) and intervention ($n=308$ players) groups are displayed in **Table 12**. A significance test for the difference between two injury rates was used to analyse the data using the VRP Injury Statistics Software, by Conor Gissane 2007. The total IR for the control group was 18.25 (95% CI 13.6-23.0) injuries per 1000 hours of participation compared to 13.31/1000h (95% CI 10.7-15.9) in the intervention group ($p=0.0719$). This IR was further broken down to reveal a post primary school control training rate of 15.83/1000h (95% CI 9.4-22.3) and match rate of 36.32/1000h compared to intervention IR of 8.78/1000h (95% CI 5.2-12.4) and 25.62/1000h (95% CI 16.9-34.4) respectively ($p=0.0629$ and $p=0.2301$). Club injury IRs revealed similar results with control training and match IRs of 15.29 (95% CI 3.1-27.5), and 35.74 (95% CI 11.0-60.5) compared to intervention IRs of 13.56 (95% CI 7.5-19.7) and IR 35.11 (95% CI 21.9-48.4) for training and matches respectively ($p=2713$ and $p=9601$).

Table 12: Hurling Lower Extremity Injury Incidence Rate

| Injuries per 1000 hrs n of Inj. | Control | | intervention | | p-value |
|---------------------------------------|---------|-----------|--------------|-----------|---------|
| | IR | 95% CI | IR | 95% CI | |
| Total (n=151) | 18.25 | 13.6-23.0 | 13.31 | 10.7-15.9 | 0.0719 |
| School (n=96) | | | | | |
| Training (n=43) | 15.83 | 9.4-22.3 | 8.78 | 5.2-12.4 | 0.0629 |
| Match (n=53) | 36.32 | 21.1-51.5 | 25.62 | 16.9-34.4 | 0.2301 |
| Club (n=55) | | | | | |
| Training (n=22) | 15.29 | 3.1-27.5 | 13.56 | 7.5-19.7 | 0.2713 |
| Match (n=33) | 35.74 | 11.0-60.5 | 35.11 | 21.9-48.4 | 0.9601 |

There was an overall 27% reduction in the rate of lower extremity injuries in participants allocated to the intervention group when compared to the control group. Results from school training revealed a 45% reduction in the rate of lower extremity injuries in the intervention group compared to the control group (see **Figure 21**). Similar results were established from competitive school hurling matches with a 30% reduction of lower extremity injury rates between the intervention and control groups. Likewise, club injury incidence rates also displayed a reduction between the intervention and control groups, however, not as large with a 11% and 2% for training and matches rates respectively.

**Figure 21:** School versus Club injury incident rates

5.1.7. Injury Rate Ratio (IRR)

The injury rate ratio (IRR) was calculated and is displayed in **Table 13**. This was used to establish the difference in injury rates between all groups of participants. Results revealed that post primary school hurling players were 61% more likely to be injured while playing a match compared to training. Similar results were established with club matches and training, with participants 60% more likely to get injured playing matches. When the control and intervention groups were compared, it was revealed that participants were 1.8 times more likely to sustain an injury while training if they were from a school allocated to the control group in comparison to the intervention schools. Participants were 1.42 times as likely to sustain an injury while playing a school hurling match for a control team compared to a school intervention team. The IRR was slightly lower for club participants, with training and match rates of 1.13 and 1.02 respectively between the control and intervention groups.

5.1.8. Injury Risk (Incidence Proportion, IP)

The risk of injury during the research period is displayed in **Table 13** and shows a 12.7% (95% CI 0.09-0.17) risk of incurring a lower extremity injury (33 players injured from 259 players that entered data) for participants involved in school hurling training and a 19.8% (95% CI 0.15-0.25) risk of injury in school hurling matches (45 players injured from 227 players that entered data). The risk of lower extremity injury while participating in competitive club hurling matches (28 players injured from 133 players that entered data) was higher at 21.1% (95% CI 0.14-0.28) while club hurling training (22 players injured from 137 players that entered data) displayed a risk of 16.1% (95% CI 0.10-0.22).

Table 13: Hurling Lower Extremity Incidence Proportion and Injury Risk Ratio

| Activity | IR | 95% CI | IR | 95% CI | IP | 95% CI | IRR | 95% CI | <i>p</i> |
|-------------------------|---------|-------------|--------------|-------------|------|-------------|------|-------------|----------|
| | Control | | Intervention | | | | | | |
| School Training | 15.83 | 9.4 - 22.3 | 8.78 | 5.2 - 12.4 | 12.7 | 0.09 - 0.17 | 1.80 | 1.01 – 3.20 | 0.0629 |
| School Match | 36.32 | 21.1 - 51.5 | 25.62 | 16.9 - 34.4 | 19.8 | 0.15 - 0.25 | 1.42 | 0.83 – 2.41 | 0.2301 |
| Club Training | 15.29 | 3.1 - 27.5 | 13.56 | 7.5 - 19.7 | 16.1 | 0.10 - 0.22 | 1.13 | 0.45 – 2.80 | 0.2713 |
| Club Match | 35.74 | 11.0 - 60.5 | 35.11 | 21.9 - 48.4 | 21.1 | 0.14 - 0.28 | 1.02 | 0.47 – 2.21 | 0.9601 |
| School Training / Match | | | | | | | 0.39 | 0.26 – 0.57 | |
| Club Training / Match | | | | | | | 0.40 | 0.24 – 0.66 | |

IR = Incidence Rate, CI = Confidence Interval, IP = Incidence Proportion, IRR = Injury Risk Ratio.

5.1.9. Timing of Injury

Hurling players reported most injuries during the month of October (19.2% from 149 players) with the following month, November (17.2% from 154 players) the next most prevalent month for injuries reported (see **Table 14**). June and July were the next most common months for injuries with 11.3% (152 players) and 9.9% (117 players) of incidences reported for each month respectively. April and September (1%) were the months with the least amount of injuries recorded, however, these two months had the lowest number of players reporting $n=41$ and $n=35$ respectively.

Table 14: Timing of injury during the calendar year

| Month of Injury | Number of Players with Data Entry | Number of Injuries | % of Total Injuries | IR/1000hrs | 95% CI |
|-----------------|-----------------------------------|--------------------|---------------------|------------|-----------|
| January | 108 | 9 | 6.0% | 1.86 | 0.6 – 3.1 |
| February | 124 | 14 | 9.3% | 1.55 | 0.7 – 2.4 |
| March | 79 | 9 | 6.0% | 1.43 | 0.5 – 2.4 |
| April | 41 | 1 | 1.0% | 0.34 | 0.0 – 1.0 |
| May | 159 | 8 | 5.3% | 1.55 | 0.5 – 2.6 |
| June | 152 | 17 | 11.3% | 2.71 | 1.4 – 4.0 |
| July | 117 | 15 | 9.9% | 2.93 | 1.4 – 4.4 |
| August | 91 | 9 | 6.0% | 2.48 | 0.9 – 4.1 |
| September | 35 | 1 | 1.0% | 0.58 | 0.0 – 1.7 |
| October | 149 | 29 | 19.2% | 4.15 | 2.6 – 5.7 |
| November | 154 | 26 | 17.2% | 3.13 | 1.9 – 4.3 |
| December | 150 | 13 | 8.6% | 2.35 | 1.1 – 3.6 |
| Seasonal | | Number of Injuries | % of Total Injuries | IR/1000hrs | 95% CI |
| Jan. – March | 311 | 32 | 21.2% | 1.59 | 1.0 – 2.1 |
| Apr. – June | 352 | 26 | 17.2% | 1.81 | 1.1 – 2.5 |
| July – Sept. | 243 | 25 | 16.6% | 2.39 | 1.5 – 3.3 |
| Oct. – Dec. | 453 | 68 | 45% | 3.27 | 2.5 – 4.0 |

When seasonal injury rates are investigated during the research period, the three months (October to December) generated the most injuries with 45% (from 453 players) of all injuries reported which is more than twice the amount for any of the other three seasonal periods during the year. July to September was the period of the year with the least amount of injuries reported with 16.6% of the injuries reported from 243 players.

5.1.10. Training Units (TUs) and Injury Incidence

The total and average player TUs for the research period are displayed in **Table 15**. The highest average TUs per player was in March (4,139 TUs) with the lowest in May (1,649 TUs). The school hurling season ran from September to April with the club season starting in April and finishing in September, with the length of both seasons dependent on how successful teams were. **Figure 22** displays lower extremity IRs together with the TUs for school and club hurling participants throughout the 12-month research period. Details displayed in Figure 22 are a visual representation of the 12-month research period, this is observational data with no correlation statistical tests completed at present.

As shown in **Table 14**, the highest injury incidence rate was recorded in October (4.15/1000hrs) which coincided with the third highest month for total training units (357,051 TUs). The most TUs were recorded during February (464,097 TUs), which was the eight highest for IRs (1.55/1000hrs). February was also the month with second highest average player TUs recorded (3,743 TUs) with the following month, March, displaying the highest average player TUs with 4,139 recorded. September had the lowest recorded total TUs (87,919 TU) and the second lowest IR (0.58/1000hrs). The lowest IR throughout the research period was April (0.34/1000hrs), which was the second lowest reported total TUs (150,315 TUs) and the third highest average player TUs recorded.

Table 15: Training Units (TUs) for the 12-month research period.

| Month | Number of Players with Data Entry | Total Training Units Recorded | Average TUs per Player |
|-----------|-----------------------------------|-------------------------------|------------------------|
| January | 108 | 251,046 | 2,325 |
| February | 124 | 464,097 | 3,743 |
| March | 79 | 326,948 | 4,139 |
| April | 41 | 150,315 | 3,666 |
| May | 159 | 262,153 | 1,649 |
| June | 152 | 316,369 | 2,081 |
| July | 117 | 262,075 | 2,240 |
| August | 91 | 184,683 | 2,030 |
| September | 35 | 87,919 | 2,512 |
| October | 149 | 357,051 | 2,396 |
| November | 154 | 429,004 | 2,786 |
| December | 150 | 283,565 | 1,890 |

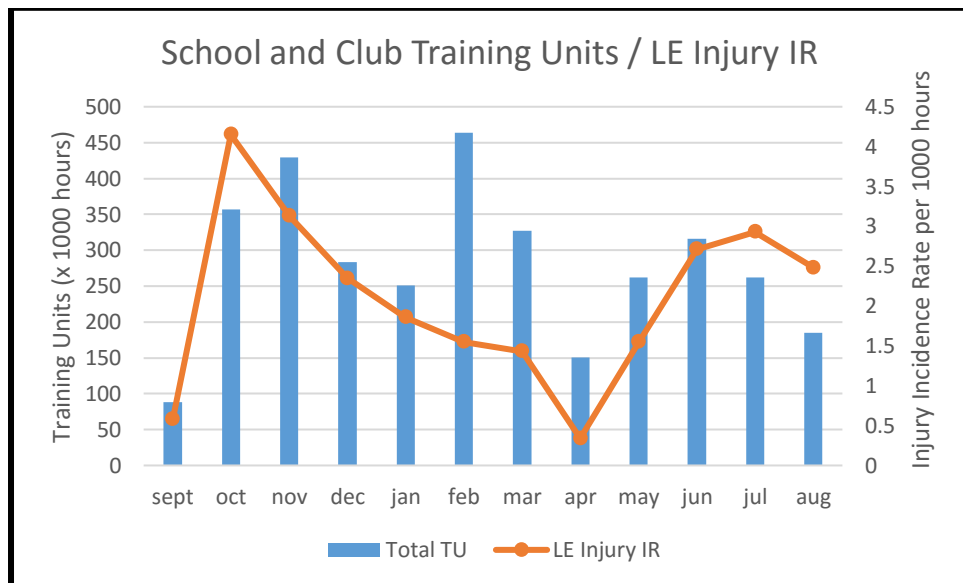


Figure 22: An Observation of Injury incidence rate (IR) in relation to total load (TU)

5.1.11. Performance Test Results

Neuromuscular performance test results for school and club participants (intervention and control, pre-test and post-test) are displayed in **Table 16**. Paired T-test results displayed statistically significant improvements in mean scores for post-test results compared to the pre-test in the 20m sprint and CMJ in three groups, school Intervention (CMJ $p<0.001$), school control (20m sprint $p=0.001$; CMJ $p<0.001$) and club intervention (20m sprint $p<0.001$; CMJ $p<0.001$). The school intervention (20m sprint $p=0.005$) and club control (20m sprint $p=0.029$; CMJ $p<0.001$) groups also displayed a statistically significant difference, however, the pre-test scores were superior to the post-test result. All Y-balance test results were not revealed to be statistically significant, with three groups (school intervention, school control and club intervention) showing deteriorations in scores from pre-test to post-test for right and left legs. The club control group did show improved scores between pre-test and post-test, however, the result was not significant $p=0.198$ and $p=0.650$ for right and left legs respectively.

Table 16: Performance test results for intervention and control group participants

| Group | Test | Pre-Test Mean Result \pm SD | Post-Test Mean Result \pm SD | Mean Diff. Pre/Post | p-value | 95% CI |
|---------------------|--------------------------|-------------------------------|--------------------------------|---------------------|---------|---------------|
| School Intervention | 20M Sprint (sec) | 3.08 \pm 0.15 | 3.13 \pm 0.13 | -0.05 | 0.005* | -0.09 – -0.02 |
| | CMJ (cm) | 47.52 \pm 5.17 | 50.04 \pm 5.50 | -2.52 | 0.000* | -3.90 – -1.13 |
| | YB Comp. Sc. (right, cm) | 90.63 \pm 6.71 | 89.61 \pm 5.86 | 1.02 | 0.437 | -1.61 – 3.65 |
| | YB Comp. Sc. (left, cm) | 91.26 \pm 6.81 | 89.80 \pm 6.03 | 1.47 | 0.201 | -0.82 – 3.75 |
| School Control | 20M Sprint (sec) | 3.20 \pm 0.19 | 3.10 \pm 0.18 | 0.10 | 0.001* | 0.04 – 0.15 |
| | CMJ (cm) | 42.68 \pm 5.67 | 48.74 \pm 6.50 | -6.07 | 0.000* | -7.90 – -4.23 |
| | YB Comp. Sc. (right, cm) | 91.78 \pm 6.91 | 89.25 \pm 6.64 | 2.53 | 0.188 | -1.32 – 6.39 |
| | YB Comp. Sc. (left, cm) | 91.02 \pm 6.86 | 89.41 \pm 7.12 | 1.60 | 0.402 | -2.26 – 5.47 |
| Club Intervention | 20M Sprint (sec) | 3.42 \pm 0.24 | 3.23 \pm 0.17 | 0.20 | 0.000* | 0.11 – 0.28 |
| | CMJ (cm) | 40.71 \pm 7.27 | 43.88 \pm 5.67 | -3.17 | 0.000* | -4.59 – -1.75 |
| | YB Comp. Sc. (right, cm) | 92.54 \pm 12.40 | 89.09 \pm 6.69 | 3.46 | 0.068 | -0.27 – 7.18 |
| | YB Comp. Sc. (left, cm) | 92.50 \pm 12.66 | 89.41 \pm 6.70 | 3.09 | 0.087 | -0.46 – 6.65 |
| Club Control | 20M Sprint (sec) | 3.15 \pm 0.15 | 3.22 \pm 0.12 | -0.07 | 0.029* | -0.14 – -0.01 |
| | CMJ (cm) | 46.93 \pm 5.44 | 43.57 \pm 6.71 | 3.36 | 0.000* | 1.65 – 5.08 |
| | YB Comp. Sc. (right, cm) | 89.25 \pm 5.49 | 91.44 \pm 6.59 | -2.19 | 0.198 | -5.58 – 1.20 |
| | YB Comp. Sc. (left, cm) | 90.20 \pm 6.98 | 90.99 \pm 6.16 | -0.79 | 0.650 | -4.32 – 2.74 |

CMJ = Counter Movement Jump; YB Comp. Sc. = Y-Balance Composite Score (right or left); p = p-value; * = Statistically Significant ($p < 0.05$); CI = Confidence Interval

5.2 Qualitative Results

5.2.1. Qualitative Analysis

Qualitative methodologies consisting of semi-structured interviews were implemented to gain a deeper understanding into the practicalities of the injury prevention strategy. Coaches/trainers ($n=6$) and participants ($n=8$) were interviewed to facilitate expression of their views and opinions of the intervention. Themes were devised as outlined below:

5.2.2. Themes

Following the coach and player interviews, four primary themes emerged and from these, eight subsequent secondary themes were established (see **Figure 23**). The primary themes were 1) the programme and content, 2) interviewees perception of programme injury prevention and performance benefits, 3) programme implementation, and 4) overall impression of the programme.

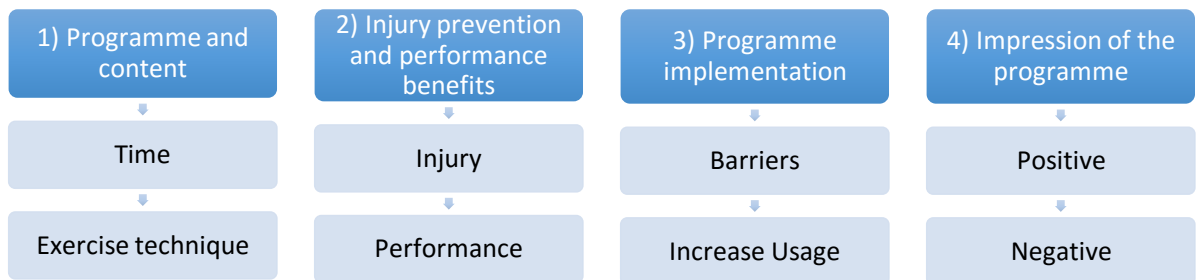


Figure 23: Primary and secondary themes to emerge from coach and player interviews

Table 17: Sample summary of qualitative interview themes and responses from team coaches and players

| QUESTION | COACHES (n=6) | | PLAYERS (n=8) | |
|---|---------------|------------|---------------|------------|
| | Yes | No | Yes | No |
| Did you think the GAA15 had any impact on reducing injury? | Yes | No | Yes | No |
| | 67% | 33% | 100% | 0% |
| Did you think the GAA15 had any positive impact on performance? | Yes | No | Yes | No |
| | 83% | 17% | 63% | 37% |
| Amount of content and time to complete the GAA15. | Just right | Too much | Just right | Too much |
| | 50% | 50% | 25% | 75% |
| Would you recommend using it? | Yes | No | Yes | No |
| | 100% | 0% | 100% | 0% |

5.2.3. GAA15 programme and content

The first primary theme focused on the contents of the GAA15 injury prevention programme, the exercises included in the programme and the length of time it took to complete. The coach interviews revealed both positive and negative comments about the length of time it took to complete, for example PT stated;

“I actually think the 20 minutes was fine because you’re actually getting a lot of ball work in that 20 minutes as well” (PT)

Similarly, when coaches’ PD and NM were asked about the length of time it took to complete, they both thought it was a bit long when they first started using it;

“I thought it was just right. At the start, I thought it was a bit too long but when I realised everything was in it, that the functional movement, you had the warming up the body, you had the stretching, you had the hand passing, you had the ball work, it touched everything” (PD)

“I suppose we found probably at the start a little tricky to get our timing down but its more down to how we interpret it, so at the start it was kind of 25 minutes with bits and bobs, we ended up getting it to about 20 minutes or 18 to 20 minutes and that really, that works, that’s why we were happy with that” (NM)

However, some of the players believed that it was a bit too long and mentioned feeling tired after completing the warm-up. When they were asked if they thought there was too much content, or possibly too many exercises to get through, players DB and JM responded;

“it was maybe a bit too long, but I thought it was quite good. By the end of it you were a bit too tired, maybe before starting a match” (DB)

“It was easy enough, you were a bit tired after it sometimes. I think maybe it was a small bit too long” (JM)

Coach MR didn’t think the IPP was needed for young players when stating;

“Young lads don’t seem to need it, or they get bored with it when they are out there for say 15 minutes, they just want to puck around” (MR)

When player JM was asked, if there was any particular part or exercise in the warm-up that fatigued him more than the other, he answered;

“No, just more all the content of it” (JM)

Coaches MR, LS and TH were asked about the technical difficulties of the exercises included in the warm-up programme and whether their players needed much correction of exercise technique;

“Ah, there was a good bit of correcting yea, with the lunging and the T plane, is that the one you get into the hamstring one, I think it needs a lot of correction for that one” (MR)

“Yea, we focused from the very start of it and then admittedly as time went on, it became natural to them, we didn’t look at it as much, their technique was much better once we focused in on, say you’re telling someone ok, to get in a knee there, or watch your squat there, watch your jump” (LS)

“The younger lads took a little while to get, it did take a while, yea” (TH)

The coaches were then asked if they thought the players improved throughout the season following the repetitive use of the warm-up exercises, they responded;

“at the start, definitely. Some of them, sure they are coming from different backgrounds, some of them were able to do it, some of them had no problem, others, it was new to them. But I thought very quickly they got up to speed at where they should be doing it” (PD)

“The single leg RDL, that kind of stuff, even things like that you could see lads, they couldn’t do five in a row without falling, they improved on that” (NM)

In the same way, players were asked if they thought the content of warm-up programme was technically difficult to complete and if they felt it got easier to do as their year progressed;

“No, not really, you kind of get better at it as you go along” (JM)

“Some of them were grand and some of them were, like the one-leg superman, that was a bit hard, you had to take your time to get it” (DB)

“Well, once you got your technique right, it was grand, everything followed through after that, no, it was alright. It was only a bit of practice you needed that’s all, do a bit yourself, kinda got you going” (JB)

When player JB was asked if he felt he improved as the year went on, he replied;

“Yea, I’d say so, your balance is better, while you’re doing the single leg stuff, it’s like, the superman stretch, you know it’s better” (JB)

5.2.4. Injury prevention and performance benefits

The second primary theme examined if the coaches and players felt the warm-up programme had any impact on injuries during the season. Similarly, it questioned coaches and players on whether the warm-up programme had any effect on their performance at the start of, and during training and competitive matches;

“Absolutely. Over the last year when we were doing it, I personally think it has reduced the amount of injuries that we would have had” (PT)

“the injuries for us were limited, I don’t know if we had a muscular injury” (LS)

“I would defiantly think so, I don’t think we had any muscular injuries. I think they were down this year. Our championship match, there was a cruciate injury, but I saw that landing, and I don’t think any warm-up would have prevented that. Other than that, we had very few injuries, I think it lessened injuries” (PD)

Other coaches weren’t sure if the programme prevented injuries because they lacked evidence from previous seasons to compare with their current season;

“I didn’t really know, it definitely didn’t get any worse as the year went on” (MR)

“for me to say it prevented injuries, I couldn’t really say, because generally it would be unusual to have a juvenile getting injured anyway” (TH)

Players JB, JM and OE believed the warm-up programme did have an effect on injuries and stated;

“yea, probably yea, like a few years ago, I struggled with my hamstrings, warm-ups like this, like activate your hamstrings even more and you’re like, it probably helps reduce that (injuries) alright” (JB)

“it was grand, I didn’t get any injuries” (JM)

“I picked up an injury in my back, but that’s because I’m prone to injuries in my back, but I didn’t pick up any injury in my leg” (OE)

The coaches and players were then asked a similar question on performance, if they felt the warm-up programme had any effect on the way they started matches or training, with regards to whether players felt or looked fatigued or if they were up to match intensity at the start of the activity;

“if anything, the intensity could have been built up sooner. We tended not to start too slowly, but a warm-up should nearly go from, warm it up, get up to match speed and then maybe catch your second wind, slow down a little bit, and then get back to match speed and then they are ready to go” (NM)

“we tried to build up the intensity so by the end they were ready to go from that situation into a match situation. We were trying to build up the intensity at match level. We were very happy” (TH)

However, coach MR felt his team needed an extra piece of work to get his players up to match intensity:

“I started to introduce a small bit of like tackling in pairs right before the game. Sometimes it (the warm-up) wasn’t enough to have them right for a game and maybe that could be just that one game they played poorly” (MR)

A selection of players suggested the warm-up had got them ready and up to match intensity, but also went on to say they were a little tired at the end of the warm-up;

“it did get you warmed up, yea, it got you up to match speed alright, you were a little bit tired at the end, that’s all” (DB)

“sometimes you’d be tired and it kinda gave you a few mins to get going from the length of it but, like if it was shortened down a little bit, you’d be more like, you have your energy saved for the start of the match and wouldn’t take you as long to get into it” (JB)

“after the warm-up, straight away after it, you’d be feeling like the legs are a bit jelly, but when you got into the match, you’d nearly forget about it. I don’t know if the legs were still tired, but in your mind, you just forget about it” (SD)

5.2.5. GAA15 Programme implementation

The third theme asked for the interviewees opinions on why other schools, clubs and teams were not using a structured injury prevention warm-up programme like this one. Several views were given with personal preference, length of time, lack of knowledge and exercise proficiency some of the suggestions offered;

“I suppose from other coaches point of view, there might be an element of maybe too much time consumption and maybe a fear of doing that before a match even” (PT)

“some teams think that their own one (warm-up) is better, whereas I think this one ticks every box and I think some people think they have to change a warm-up the whole time to keep players fresh. But maybe, I was thinking that myself until I saw this and I just thought that the players really like this, they knew exactly what was coming next” (PD)

“unless it’s the coach himself that had a preference, that they wanted to do a possession game or they had their own favourite one (warm-up)” (MR)

“the barrier maybe is just maybe the lads over a team, the coaches maybe they feel they mightn’t, you know, sometimes when it comes to, people maybe feel some of the stretches are a bit technical and they don’t want to be telling players to do the wrong thing so I think it’s about the coaches themselves really” (TH)

Some of the players gave similar answers, suggesting, that other coaches were reluctant to change from what they always did;

“they (coaches) probably don’t know enough, they don’t know these exercises or don’t know how it’ll help the players or how it will help a team. They just know what they’ve started off with, and always continued with that, and see what has worked for them from the start, but shur they are not open to anything else or open to change” (JB)

“maybe a lack of knowledge about what to do with training and coaching” (DB)

“a lack of knowledge really, maybe if clubs knew about things like this, they would be using it the whole time. What they know is go out into lines and pucker the ball to warm up your touch, and that’s really it then” (PM)

Interviewees were asked, how did they think it would be possible to increase the overall usage of a structured warm-up programme like this one with other school and club teams. Coach PD suggested using the results from this investigation as a way to inform

other team coaches while coach LS recommended getting coaches involved in this research to advise others as to its benefits;

“if word got out from the people that used it, that it was good and then I suppose, the research, the results of it, we can show that there’s less injuries coming out of it, sure then why wouldn’t you, why wouldn’t you use it” (PD)

“you need to get the people who have done it to basically tell the others that this has worked” (LS)

“a lot of it is education, it’s kind of going from, well look we’ve worked with high level things and obviously it is all about injury prevention and that’s what clubs need to lean towards and not injury treatment” (NM)

Players JB and SD, in the same way, suggested education as a possible way to increase the usage of a structured injury prevention warm-up;

“all the coaches from other clubs come in, if you had a presentation or something with warm-ups that they should use or could use, it would be up to themselves then if they wanted to use it or not, they would know about it then” (JB)

“probably people don’t know about it, that’s probably the main thing like. Lads think of going to a match, they don’t really think of the warm-up that much, even the manager probably doesn’t even think about it. But if managers were to sit down at the start of the year, you could discuss what they were going to do in the warm-up, and then say, well, maybe get a bit of information on what we should be doing, the right kind of thing like. That kind of thing like, maybe if they could be more informed about it, then I’d say people would use it” (SD)

5.2.6. Impression of the GAA15 programme

The fourth and final theme to emerge from the interviews focused on the coaches and players overall impression of the GAA15 structured warm-up programme. Several of the coaches gave positive feedback following the use of the programme, with coach PT complimentary on the fundamental movement aspect and coaches TH and PD approving of the structured layout of the programme so that players knew exactly what was coming next and they just got on with the warm-up themselves;

“when I saw it, straight away, I was really impressed by it, the players liked it. Definitely because they knew every time, and where I really found it beneficial was before an important match, they were so used to doing this, that it was just second nature” (PD)

“I thought it was very good, and I thought it was good from the aspect of the 20-minute warm-up involved movement all the time and the other thing that strikes me is that they were moving with a ball” (PT)

“it was a great, it kind of gave us a great structure I thought, we left the dressing room and we had a good 10 minutes where we had something that was formulated and it was standardised and everyone knew, and after a few sessions, everyone knew exactly what to do” (TH)

Players also liked the structured nature and familiarity of the warm-up programme, with player JB admitting it was very different to the warm-ups he normally did at club level;

“it was good, it was different compared to other warm-ups that I have done, like other warm-ups would be doing stuff in straight lines, this one activates different muscles that you wouldn’t be doing in other warm-ups. It gives you an all-round activation for all your muscles. With clubs, especially, you jog out straight, and you line up in straight lines, there’s no real sideways movement or circular movements” (JB)

“it was definitely different to what we normally do anyway. It seemed more, eh, technical than you’d normally do in a warm-up, where you just go high knees and all that, eh, like activating and things like that. You’d have less of a fear of having an injury then because it feels like you’re doing something that could actually warm you up properly” (SD)

In general, the comments from both the coaches and players were positive following the use of the GAA15 warm-up programme, however, coach NM did mention an issue with some of his players cramping during matches;

“the only thing I suppose that we found in our team, it could have nothing to do with it, or anything to do with it, in the county semi-final and mainly the county final, we picked up 3 or 4 lads went off with cramp, now, it could be down to a number of factors, I don’t think personally it was down to the warm-up before it or lack thereof or whatever, I think it was the intensity of the game and tension the night before obviously. It was calf, all calf actually and I would have added the steps on the calf as part of the warm-up, where you walk on the toes with dynamic calf stretches and static calf stretches” (NM)

Player PM also revealed his calf muscles were tired after completing the warm-up;

“your calves would be a bit tired after it alright” (PM)

Player SD felt there might be too many lower limb exercises and spoke about his legs feeling tired after the warm-up;

“before matches and things like that, you’d nearly be tired coming out of it sometimes. There was nearly too much activation like, you do the lunges, and then you do squat jumps, and you actually feel like the legs are gone a bit jelly like. Things like that, but, nothing over tiring or anything like that. Just one or two exercises too much is all” (SD)

Finally, coaches and players were asked if they would recommend using a structured injury prevention programme like the GAA15 warm-up before matches and training sessions;

“I suppose players need a kind of a template, I would imagine to get the real success out of that warm-up, if you were constantly doing it, if the lads were doing it in school, they were going into the squads (County GAA development squads) and doing it. Now I don’t know how many squad coaches would actually use that at the moment, I think it would be very beneficial. To me, the movement that is in it, the ball work that’s in it, I mean what do you look for in a warm-up? There’s everything in that warm-up” (PT)

“I certainly would yea, as I said I’m involved with the senior (adults) team this year and we do that for every training session, the same thing yea” (TH)

“I definitely would, yea, I’d recommend it alright, I think there was a nice structure to it, the way it was laid out, I thought it was very good, yea” (MR)

Coach LS agreed and further suggested modifying the warm-up while using the important components of the programme;

“absolutely, yea, I would recommend it, with your own tweaks, whatever you want to bring into it yourself, with the components of it (GAA15)” (LS)

Player JB was impressed with the familiarity of the warm-up programme structure and would be happy to use the GAA15 with all teams he was involved with;

“you’d know what you were doing every single time you went out with a different team, you’d know it was the same, not like you can use the excuse like this warm-up is that, at least you’d have the same warm-up for every team” (JB)

It is evident from the information received from the interviews and summarized in **Table 17** that the GAA15 injury prevention programme used in the current study was very well received. Overall both the coaches and players were 100% satisfied to use the GAA15 and were also happy to recommend it to others. It was interesting to note that 75% of the players felt that the programme took too long to complete or that there was too much content in it, with 50% of the coaches interviewed agreeing. It could be suggested that future research look at different versions of the GAA15, with regards structure, length of time to complete, content included and training/match versions of the programme.

Chapter 6: Discussion

6.1. Introduction

The main objective of this current investigation was to evaluate the effectiveness of the GAA15 injury prevention programme (IPP) in reducing injuries in adolescent males participating in hurling. Additionally, the effect of the GAA15 on neuromuscular performance measures, pre to post season, were analysed within each group to determine if any neuromuscular adaptations were attributed to the IPP. Finally, deeper insights into the practical implementations of the GAA15 IPP were obtained following semi-structured interviews with team coaches and players. The findings from each of these objectives are discussed separately in the respective subsections.

6.2. Summary of Results

The results of this investigation demonstrate that positive results can be achieved from the implementation of a neuromuscular injury prevention warm-up, namely the GAA15, in reducing lower extremity injuries in adolescent males participating in hurling. As a result, the subsequent hypothesis was accepted:

- Implementation of the GAA15 neuromuscular injury prevention programme will decrease injury incidence in adolescent males participating in hurling.

Additionally, the following hypothesis can be rejected:

- Neuromuscular intervention strategies (GAA15) will positively affect neuromuscular performance measures from baseline to end of season scores.

6.3. Injury Prevention

It has previously been suggested that IPPs should be a fundamental part of any team's preparation for competition (Owen et al. 2013). FIFA, in response to the growing rate of injuries in soccer, developed the FIFA11 IPP in 2006. Numerous investigations executed world-wide proved its effectiveness in reducing injuries (Owoeye et al. 2014; Silvers et al. 2014; Bizzini & Dvorak 2015). Evidence from previous research on the utility of the FIFA11 suggests that it is possible to achieve injury reductions of between 30 to 70% by using the programme two to three times per week before training and matches (Grooms et al. 2013; Owoeye et al 2014; Silvers-Granelli et al. 2015). Similarly, other injury prevention programmes like the Prevent injury, Enhance Performance (PEP) (up to 88% reduction in injuries), Knäk kontroll (64% reduction), and PAFIX (22% reduction) displayed comparable results (Mandelbaum et al. 2005; Waldén et al. 2012; Finch et al. 2015). In the same way, this current investigation established positive results favoring the intervention group, using the GAA15 IPP, with a 27% reduction in all lower extremity injuries when compared to the control group participants (IR 18.25 and 13.31/1000hrs respectively). It has previously been reported that variations in injury definitions and methodologies between sports create differences in study outcomes and conclusions and although other studies have tried to standardize injury definition, there remains significant variation (Fuller 2006; Clarsen & Bahr 2014). For the purpose of this study an injury was defined as "any injury sustained during hurling training or competition resulting in time lost from play or athlete reported restricted performance" (Brooks 2005; Murphy et al. 2012; O' Connor et al. 2016).

6.3.1. Injury Incidence

Incidence Rate (IR)

The overall injury IR for the current study was 21.53 injuries per 1000 hours of activity (95% CI 18.8-24.3). This was further broken down to reveal a lower extremity IR of 14.75/1000hrs (95% CI 12.5-17.0) with training injuries accounting for 12.10/1000hrs (95% CI 9.3-14.9) and a match IR of 31.18/1000hrs (95% CI 24.7-37.6). The rate of injury

was considerably higher for matches compared to training despite all participants spending more time training than playing competitive matches. These results are consistent with other hurling studies showing an increase in injury incidence while participating in matches (Murphy et al. 2012; Blake et al. 2014; O' Connor et al. 2016). Other multidirectional field sports reported similar findings with soccer, lacrosse, and Australian rules football all recording higher rates of injury during matches when compared to training (Emery et al. 2005; Finch et al. 2009; Kerr et al. 2016).

The overall injury rate was shown to be considerably higher than a previously reported investigation of 21 adolescent soccer teams aged between 12 and 18 years, which reported 5.59 injuries per 1000hrs (Emery et al. 2005). However, this soccer study consisted of adolescent boys ($n=153$) and girls ($n=164$), furthermore, injuries were assessed, firstly by the team athletic therapist and subsequently by a sports medicine physician which may contribute to the disparity in IRs between their study and the current study. It is also probable that self-reporting of injuries, as used in this current study, may result in higher rates being recorded, which was highlighted in a previous study examining the prevalence of self-reporting injuries versus actual diagnosis in elite female athletes (Øyen et al. 2009). In this study, it was established that more of the athletes self-reported stress fractures (14%) when compared to the athletes who were diagnosed by clinical criteria (8%). Reasons presented for over-reporting was athletes' unfamiliarity with the classification of injury used in the investigation. Similarly, it is possible that some of the adolescent players in the current study failed to understand the injury definition provided and as a result over reported incidences. It is also probable that players over reacted and self-reported injuries when in fact no injuries were sustained. There are many theories that may account for this motive that go beyond the scope of this research.

The reported IR (21.53/1000hrs) in the current study was higher than adolescent lacrosse (12.98/1000 per Athletic Exposures) which could be considered comparable to hurling with players using sticks to play a multidirectional physical contact game (Kerr et al. 2016). However, the lacrosse investigation had an athletic trainer reporting injuries and exposure details for each team, consisting of young children from the age of nine (up to 15 years), which may have contributed to the low rates of injury displayed. In addition, injury rates were calculated per athlete exposure (defined as one player

participating in one game or one training session) and not per hour of participation. Furthermore, injuries were defined as any injury that occurred during a league-sanctioned game or practice session that required the athletic trainer's evaluation and attention.

When compared to adult hurling players (training IR 2.99/1000hrs and match IR 61.75/1000hrs), the results of this study established a training injury IR of 12.10/1000hrs, which is four times higher than those of the adults and a match injury IR of 31.18/1000hrs, which was half the reported adult IRs (Blake et al. 2014). The sizeable disparities in injury rates observed could be due to the age of the adolescent participants in this study compared to adult players (over 18 years) in comparable studies. It has been suggested that adult players are physically more developed and play matches at a higher intensity at elite level which could reflect the higher rates of injury during match play (Murphy et al. 2012). It is not obvious why the reported training IRs in the current study are higher than comparable adult hurling studies, however, it could be speculated that elite adult players are more physically conditioned than adolescent players which could place the younger player at a greater risk of sustaining training injuries. Despite having similar injury patterns to adults, other factors such as skeletal, physiological, psychological and hormonal maturity along with fitness and skill levels need to be carefully considered when comparing injury rates between adults and adolescents (Scase et al. 2012).

Research investigations involving adolescent GAA players is scarce, however, one previous epidemiological study revealed 2.29 hurling injuries per 1000 hours of training, and match injuries of 11.11 per 1000 hours of participation (O' Connor et al. 2015). Similar IR results were discovered in Gaelic football with training and match injuries of 3.01/1000hrs and 9.26/1000hrs respectively (O' Connor et al. 2015). In this investigation, injured participants were assessed by the lead researcher during a weekly clinical examination where injury report forms were completed and recorded. Furthermore, all participants were under 16 years of age, and as a result generalization to younger or older adolescents should be executed with care.

Adolescent athletes experience similar injuries as their adult counterparts, however, care needs to be taken during periods of rapid growth as they can be at risk of damaging growth plates, apophysis and joint surfaces (Soprano & Fuchs 2007). It has also been

suggested that adolescents are at risk of overuse injuries because of rapid increases in training volume along with poor quality coaching (Soprano & Fuchs 2007). Furthermore, Grady & Goodman (2010) stated that the biomechanical changes that occur during times of rapid adolescent growth could predispose these young athletes to injury.

Injury Rate Ratio (IRR) – Intervention v Control

The current research reported a 45% reduction in lower extremity training injury rates in the school intervention group compared to the schools control group (control IR 15.83/1000hrs, intervention IR 8.78/1000hrs). These findings are consistent with other multidirectional field sports IRs such as soccer (control 15.04/1000hrs; intervention 8.09/1000hrs) and Australian rules football (control 14.7/1000hrs; intervention 11.8/1000hrs), reporting 46% and 20% reductions respectively (Finch et al. 2015; Silvers-Granelli et al. 2015). The reported injury reductions in school participants was shown to be greater than the results of a systematic review and meta-analysis of the FIFA11 programme which was shown to have an injury-preventing effect of reducing soccer injuries by 39% (Thorborg et al. 2017). It is acknowledged that the % decrease in IRs in the current study is not statistically significant ($p=0.0629$), but from a practical viewpoint, the reduction of injuries exhibited should encourage team coaches to consider using IPPs like the GAA15 to assist in the reduction of lower limb injuries. It has previously been recommended that along with clinical and statistical significance, a third type of significance be proposed, “patient significance” (Sedgwick 2014). Likewise, it was suggested by Kalinowski & Fidler (2010) that the importance of a study result depends on much more than its statistical significance, and suggested practical importance be measured and judged on its own right. Similarly, Hopkins (2006) suggests Magnitude based Inferences (MBIs) as another statistical method of practically looking at research results: a potential future recommendation.

There was a 30% reduction in the rate of lower extremity match injuries in school adolescent male hurlers participating in the intervention GAA15 IPP (control group 36.32/1000hrs v’s intervention group 25.62/1000hrs). In contrast, club participants displayed a less dramatic reduction of 11% in the intervention group (control 15.29/1000hrs v’s intervention 13.56/1000hrs) in training, and 2% (control 35.74/1000hrs v’s intervention 35.11/1000hrs) in lower extremity match injury rates.

The considerable differences in the rates of training (45% & 11%) and match (30% & 2%) injury reductions between the school and club participants in this study suggest that, implementation, understanding and compliance of the GAA15 may have been confounding factors for team coaches at club level. This theory is supported by Thorborg et al. (2017) who suggested that poor IPP compliance, of at least two sessions per week, could restrict achieving the optimal benefits. Other possible reasons for poor results have previously been suggested, with IPP dissemination failure, translation/adoption failure and research relevance failure being advocated (Finch 2011). It was hypothesised that schools offered a better likelihood of programme uptake and compliance with participants attending school on a daily basis. School hurling training sessions and competitive matches were more regulated as school attendance is compulsory and as a result compliance would have been expected to be better.

School participants were 61% more likely to incur a lower extremity injury while playing a match compared to training with similar results (60%) discovered in club players. Overall, match injuries were more prevalent than training injuries in this investigation, however, the results were noticeably less than one previous adolescent GAA study, (O' Connor et al. 2015), with participants 4.85 times more likely to be injured playing a match compared to training. Results were even greater at senior (adult) level, with two former prospective studies (Murphy et al. 2012; Blake et al. 2014) showing participants 20.7 and 19.3 times more likely to obtain an injury while playing a match compared to training. While investigating the efficacy of the FIFA11+ in adolescent soccer players, Owøye et al. (2014) discovered similar results to the current study with soccer players twice as likely to pick up a lower extremity injury while playing a competitive match compared to training. Likewise, adolescent lacrosse players displayed comparable rates of injury to adolescent hurling players, with players 2.9 times more likely to sustain an injury during a competitive match compared to training (Kerr et al. 2016). While tracking 532 elite junior (under 18 years) Australian rules footballers during one season, Scase et al. (2012) established that participants were almost three times as likely to be injured while playing a match when compared to training. An increased risk of injury is evident in competitive matches, this is indicative of the higher intensity required in games when compared to training sessions.

6.4. Location of Injury

A large proportion of injuries reported were to the lower extremity (66.5%), which is consistent with previous hurling research (Murphy et al. 2012; Blake et al. 2014; O' Connor et al. 2015). It has previously been reported that the lower extremity is the most frequently injured region of the body during a variety of similar multidirectional field sports (Caine et al. 2008; Habelt et al. 2011; Faude et al. 2013). Similarly, it has been established that 59.65% of all Gaelic games injury scheme claims during an 8-year period (2007 to 2014) was for lower limb injuries (Roe et al. 2016). The upper extremity was the next most injured body region with 26.9%, with the head, neck and spine the least injured region of the body with 6.6% of all injuries recorded. This is in contrast to a former study on adult hurling players, who reported a total of 15.2% injuries to the upper body and 14.7% to the head, neck and spine (Murphy et al. 2012).

In a recent adolescent epidemiological study, by O' Connor et al. (2016), a high prevalence of lower extremity injuries in both hurling and Gaelic football, 58% and 74% respectively were reported in one playing season. Collegiate Gaelic football players also recorded comparable results with 71.1% of all injuries being reported to the lower limbs (O'Connor et al. 2016). Additionally, senior adult hurling players produced similar findings from a five-year prospective study, with the majority (68.3%) of all injuries reported, to the lower limbs (Blake et al. 2014). A four-year prospective study on adult Gaelic football produced consistent results, with 76% of all injuries recorded to the lower extremity (Murphy et al. 2012).

Adolescent lacrosse previously reported slightly lower rates, with 45.2% of all injuries reported classified as lower extremity injuries and just over half of these being contusions (Kerr et al. 2016). Higher rates of lower extremity injuries were reported in adolescent soccer with 78.2% of all injuries recorded in one investigation featuring adolescents from 21 soccer teams from three different age groups (under 14, under 16 and under 18 years) (Emery et al. 2005). Likewise, Australian rules football documented similar results, with 72.2% of all new injuries reported in elite junior (under 18 years) players being to the lower limb (Scase et al. 2012).

A consistent theme is emerging across injury location in multidirectional field sports and GAA in particular, and that is, lower extremity injuries are a prevalent issue across all ages.

Injury Site

The knee was the most frequently injured body part with 14.5% of all injuries registered. Inadequate neuromuscular control has been proposed as one of the potential risk factors for knee injury (Weeks et al. 2012). Similarly, Alentorn-Geli et al. (2009) previously identified muscular fatigue caused by altering neuromuscular control as a commonly reported knee injury risk factor. Adolescent lacrosse and soccer reported similar rates of knee injury with 12.3% and 19% respectively (Emery 2003; Kerr et al. 2016). A recent investigation of adolescent GAA players reported higher rates of knee injuries in both hurling and Gaelic football players with 20% and 18.7% being recorded respectively (O' Connor et al. 2016). Adult hurling players have previously recorded lower rates of knee injury (11.9%) when compared to the current study, with adult Gaelic football players (11.3%) also reporting lower results (Murphy et al. 2012; Blake et al. 2014). Knee injuries are multifactorial in nature and are commonplace amongst field sport athletes with the GAA being no exception to this. Any reduction in knee injuries amongst adolescent athletes as ascertained in the current GAA15 IPP has to be worthwhile.

Unsurprisingly, for a physical contact game like hurling, that uses a piece of equipment (camán), the hand was the next most frequently injured body part, with 11.5% involvement. Other sports using instruments to play their games displayed contrasting results, with lacrosse recording 7.1% and ice hockey registering only 1.1% of hand injuries (Agel, Dompier, et al. 2007; Kerr et al. 2016). However, it should be noted that lacrosse would be more akin to hurling with rising and striking involved, whereas the ice hockey puck stays on the ice i.e. no rising, and ice hockey players also wear protective gloves. Despite injuries to the hand being commonplace in hurling, a previous study reported very low usage (8%) of voluntary hand protection being used even though a similar investigations established 52% and 62% of hospital emergency department presentations were for hand injuries during hurling (Crowley et al. 1995; Falvey et al. 2013).

The hamstrings (9.7%) and quadriceps (9.7%) equally were the next most frequently injured region of the body reported by all participants. These findings are in contrast with a previous investigation of elite adult hurling players during one season, where 16.5% of all injuries recorded was to the hamstrings (Murphy et al. 2012). Higher rates were also reported during a five-season investigation of elite adult hurling players, with 22.9% of injuries to the thigh region, however, the breakdown between anterior and posterior thigh was not reported (Blake et al. 2014). Elite adult Gaelic football players recorded considerably higher rates of hamstring injuries with almost one quarter (24%) of all injuries during a four-year prospective study (Murphy et al. 2012). Other previous studies on adult Gaelic footballers produced mixed findings with hamstring injury rates of between 12% and 22% being reported (Cromwell 2000; Newell et al. 2006; O'Connor et al. 2016). A greater hamstring injury incidence has previously been established in adolescent Gaelic footballers than hurlers with rates of 13.3% and 4% being reported respectively (O'Connor et al. 2016). The results of previous GAA research into injury epidemiology highlights the need for injury prevention programmes in this group to help prevent lower extremity injuries.

Lower back injuries were the most injured body region (22%) in one previous investigation (O'Connor et al. 2015) and this is in contrast to the current study, with 2.6% of lower back injuries reported. Only 5.3% of Gaelic footballers, in the same study, reported lower back injuries, which makes the high rates reported for the hurling players difficult to explain and requiring further investigation.

6.5. Timing of Injury

The largest proportion of injuries were reported in the month of October with 19.2% (4.15/1000hrs. 95% CI 2.6–5.7) of all injuries recorded from 149 players that entered data. The following month, November, was the second highest month for injuries reported with 17.2% (3.13/1000hrs. 95% CI 1.9–4.3) from 154 players. Previous literature has established that there is a greater risk of injury while playing competitive matches than by training (Murphy et al. 2012; Blake et al. 2014; O'Connor et al. 2016). It could be suggested that adolescents returning to school in September, following the

summer holidays, play more matches at this time of the year because school GAA has commenced and players are involved in both club and school GAA activity. It is also highly probable that some adolescents are involved in other sports, like rugby and soccer, who also commence their seasons around the start of the school year (September). Interestingly, the lowest number of injuries were recorded in September with the highest and second highest recorded during the following two months, October and November respectively. However, it should be noted that September had the lowest player compliance for entering data with 35 players and October and November having the fifth and second highest player compliance with 149 and 154 players entering data respectively. The rapid increase in match and training activity, presented as training units (TUs), at the beginning of the school year, illustrated by 87,919 TUs recorded in September and 357,051 TUs in October is subsequently followed with the greatest rise of injuries reported in the same period (September IR 0.58/1000hrs, October IR 4.15/1000hrs). On the other hand, when average player TUs are examined for the same 2-month period, there is an actual decrease in load between September and October with 2,512 TUs and 2,396 TUs respectively with a noticeable increase from October to November (2,786 TUs). Interestingly, the highest average player TUs were recorded during the 2-month period February (3,743 TUs) and March (4,139 TUs), which coincides in the culmination of the school hurling championships and the start of pre-season for club GAA activity. It has been suggested by Gabbett (2016) that players experiencing excessive and rapid increases or spikes in training load could be responsible for a large proportion of soft tissue injuries. Likewise, O'Connor et al. (2016) speculated that the high number of injuries recorded in October may be due to players coming to the end of their club seasons, while beginning their schools GAA campaign. A strong relationship between high volumes of training load and increased risk of injury has been reported in the literature, however, more recent literature implies that week to week changes in training volume could also have an impact on injury risk (Gabbett 2016). Monitoring training load is an important part of physical preparation for sport with Gabbett (2016) suggesting both recent (acute) and medium-term (chronic) training load data as the best way to obtain a players training burden. Gabbett (2016) further advocates the critical variable (acute : chronic workload ratio) as a way of intervention to help reduce injury risk and time loss from sport.

The current results are in contrast to a previous study (O' Connor et al. 2015) that reported February as the highest month for injuries in their adolescent GAA investigation. However, that study consisted of male adolescent GAA players under-16 years of age, while this current investigation looked at participants playing hurling on teams that encompassed two different age profiles, under-18.5 and under 14.5 years. The post primary schools GAA calendar operates at different times of the year, depending on the sport (Gaelic football or hurling) and age groups, which may explain the timing (months) differences in injury rates between the two studies. Interestingly, similar numbers of injuries were previously reported in one epidemiological study in collegiate GAA players during October (23.9%) (O'Connor et al. 2016). However, only two colleges (third-level) were involved in the study and with different numbers of matches and training sessions recorded for the duration of the study, care needs to be taken when comparing injuries to post primary (second-level) school teams.

6.6. Neuromuscular Performance Measures

When the performance test results were analysed, improvements were recorded in the CMJ in the two intervention groups, school intervention ($p < 0.001$), club intervention ($p < 0.001$), while the 20m sprint also improved in the club intervention ($p < 0.001$) group following the use of the GAA15 warm-up programme. However, improvements were also recorded in the school control group for the 20m sprint and CMJ, $p = 0.001$ and $p < 0.001$ respectively while using their own warm-up routine. Root et al. (2015) previously established, by using neuromuscular IPPs, it can improve movement based risk factors such as stiff landings, knee frontal plane motion and increased hip and knee rotation. Additionally, it has been reported that the content and volume of IPPs may also be a factor for neuromuscular improvement during jumping and landing exercises (O'Malley et al. 2016). Following the intervention period, the average 20m sprint times in the school intervention group was slower in the post-test (3.13sec \pm 0.13) when compared to the pre-test (3.08sec \pm 0.15) result ($p = 0.005$).

Only one group (club control group) displayed an improvement in Y-balance scores between the pre-test and post-test, with 89.25cm \pm 5.49 (pre-test) 91.44cm \pm 6.59 (post-

test) and $90.20\text{cm} \pm 6.98$ (pre-test) $90.99\text{cm} \pm 6.16$ (post-test) recorded for the right and left leg composite scores. The other three groups (school intervention, school control and club intervention) all recorded scores that deteriorated between the pre-test and post-test. It is somewhat surprising that no improvements were noted in the Y-balance test for the intervention groups following the use of the GAA15 IPP. It is suggested that this might be related to some team's non-compliance of all or some of the components of the GAA15 such as the single leg balance and strength exercises.

The neuromuscular performance tests carried out in this current study displayed mixed results between the pre-test and post-test assessments. It could be speculated that participants were less motivated for the post-test assessments considering their respective teams had just recently been knocked out of their hurling competitions. It was noted that participants and team coaches were enthusiastic and highly motivated during the pre-test assessments, however, most were less interested in the post-test assessments. This wasn't reported in the qualitative analysis section, this is what was observed by the lead researcher prior to and during the post-testing assessments. Any further investigations, which take these variables into account, will need to look at a set intervention time period for the pre-to-post-test performance assessments, which would help to improve player and coach motivation.

6.7. Qualitative Analysis

Identification of individual and social factors that may influence the implementation of IPPs can provide important fundamental information for the future design, adoption, implementation and maintenance of these interventions (O'Brien & Finch 2016). Furthermore, Finch (2011) suggests, for an IPP to have long lasting effects, it needs to be adopted, sustained and to be properly maintained by having proper structural systems in place to support its compliance. The impressions and insights of the GAA15 IPP, from the coaches and players' perspectives, were gained by the introduction of the semi-structured interviews; these were executed at the end of the intervention period. In general, the responses from coaches and players were very positive, with those interviewed happy to use an IPP warm-up programme like the GAA15 in the future, with

the majority stating that they would also recommend it to others. The issue of programme length and monotony are items that could be explored in future research. Consideration could be given to the different age groups, coaches knowledge and beliefs, with one coach suggesting; *“maybe it could be something to look into, shorter warm-ups for under-14’s and add an extra few minutes for each age group up to under-18” (MR)*. Similarly, while investigating the perceptions of coaches after using the FIFA11 IPP, O’Brien & Finch (2016) discovered some coaches found the programme *“too monotonous for regular use”*. Furthermore, most of the coaches in that investigation felt the FIFA11+ programme needed *“improvement for use with their team”*.

6.8. Limitations

One of the main limitations of this study was that GAA15 IPP compliance was not monitored. Due to the large number of participants and the varied geographical locations of the participating schools and clubs, it was difficult to visit and observe teams implementing the programme on a regular basis. Furthermore, the GAA15 consists of a number of components, which makes the adoption and implementation problematic, supervision was not provided and therefore it was a concern whether teams were using it correctly or in the structured manner in which it was developed. Following some spot checks by the lead researcher, it was noted that some teams had altered the intervention programme and were using their own version of the GAA15 which wasn’t in accordance with the instructions provided at the beginning of the research. In addition, there was no record of the amount of times per week teams were using the GAA15 IPP during the season.

Another limitation for this study was participants compliance in completing their daily wellness report on their mobile phone application. Players reported on sport participation, training load and injury incidence (when applicable) throughout the investigative period. Players were notified up to four times per week to fill in their

wellness details, by means of a text message, however, compliance was a major issue from the start of the research. It was observed that school hurling team participants tended to have better compliance when compared to club teams, with school team coaches seeing their players five days per week during their school hurling season, compared to maybe two or three days per week at club level.

The difference in the numbers of participants between the two groups, intervention ($n=537$) and control ($n=284$), was largely due to the geographical location and the primary researchers accessibility and time constraints given the scale of the study. Due to the large numbers involved and the time taken to organise the intervention teams prior to the commencement of their season, organising control participants proved challenging. Future research could look at setting up teams before the end of a school term in preparation for the upcoming school GAA season.

An additional observation and consideration from this research is that the adolescent cohort were generally six months older at the end of the research than when they commenced. It could be speculated that adolescents, through the natural biological growth period, over this time frame affected their natural ability to be able to run faster, jump higher and be physically stronger which would have a bearing on the results. Similarly, it has previously been reported that exercise programmes could have a larger physical effect in younger adolescents because they might not have started their basic movement patterns (Soligard et al. 2008)

As previously mentioned, the enthusiasm and motivation from both the participants and team coaches before and during the initial performance test was very noticeable by the lead researcher, possibly because the tests were novel and something they generally hadn't completed before. However, the opposite was apparent before and during the neuromuscular performance post-test assessments, with coaches and players generally lacking motivation to achieve the best results possible. Another issue was trying to schedule schools and clubs for post-test performance assessment, with exams, matches and holidays commonly used as barriers to fulfilling post-test appointments.

Following the analysis of the performance test results, it could be suggested that a general lack of information on what the control group were doing during their warm-up routines could be seen as a limitation. It is possible that some control teams were implementing a structured injury prevention warm-up of their own, but the information

on this was outside the scope of this research and was not captured. This could possibly explain the positive results in the control groups compared to the intervention groups during some of the post-test performance assessments. In addition, it would be interesting to analyse between group performance data and correlate this to the epidemiological data.

6.9. Future Recommendations

Due to the proposed lack of motivation for the post-test performance assessments, when teams were knocked out of their competitions, it could be suggested that a specific intervention period (10 to 12 weeks) be proposed in any future research. Intervention period starting dates could be staggered to allow for testing scheduling. Furthermore, by making performance test results available to participants, this may help with motivation to improve scores.

Recording mobile phone wellness data by participants could be improved by allocating sufficient time for overseeing player data input, evaluating and interpreting the results and providing necessary feedback to players, by team coaches or an appointed person. It was previously stated by Saw et al. (2015) that team management should play a role in the implementation of self-reporting measures by creating a positive culture through education and trust in the process, which may not have been the case in the current investigation.

Because of the widespread GAA calendar for the different age groups as well as players partaking in more than one age group and or playing level, data collection and intervention compliance could be improved by focusing on one particular age group at a specific time of year (League or Championship). Furthermore, a randomised control trial with analysis of clustered data for one particular age group would provide much needed age-specific statistics and information for the GAA.

6.10. Conclusions

Performing “research to practice” behaviour is paramount in injury prevention research. Implementation of the GAA15 injury prevention programme can assist in reducing lower extremity injuries in adolescent males by up to 45% when compared to age matched control participants.

References

- Abernethy, L. & Bleakley, C., 2007. Strategies to prevent injury in adolescent sport: a systematic review. *British journal of sports medicine*, 41(10), pp.627–638.
- Agel, J. et al., 2007. Descriptive epidemiology of collegiate men’s ice hockey injuries: National Collegiate Athletic Association injury surveillance system, 1988-1989 through 2003-2004. *Journal of Athletic Training*, 42(2), pp.241–248.
- Agel, J., Arendt, E.A. & Bershadsky, B., 2005. Anterior Cruciate Ligament Injury in National Collegiate Athletic Association Basketball and Soccer: A 13-Year Review. *American Journal of Sports Medicine*, 33(4), pp.524–531. Available at: <http://ajs.sagepub.com/lookup/doi/10.1177/0363546504269937>.
- Alentorn-Geli, E. et al., 2009. Prevention of non-contact anterior cruciate ligament injuries in soccer players. Part 1: Mechanisms of injury and underlying risk factors. *Knee Surgery, Sports Traumatology, Arthroscopy*, 17(7), pp.705–729.
- Andrzejewski, M. et al., 2013. Analysis of sprinting activities of professional soccer players. *Journal of strength and conditioning research / National Strength & Conditioning Association*, 27(8), pp.2134–40. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/23168374>.
- Arnason, A. et al., 2004. Risk factors for injuries in football. *The American journal of sports medicine*, 32(1 Suppl), p.5S–16S.
- Arvinen-Barrow, M., Massey, W. V. & Hemmings, B., 2014. Role of sport medicine professionals in addressing psychosocial aspects of sport-injury rehabilitation: Professional athletes’ views. *Journal of Athletic Training*, 49(6), pp.764–772.
- Backous, D.D. et al., 1988. Soccer injuries and their relation to physical maturity. *American Journal of Diseases of Children*, 142(8), pp.839–842. Available at: http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L18180333%5Cnhttp://sfx.ub.rug.nl:9003/sfx_local?sid=EMBASE&issn=0002922X&id=doi:&atitle=Soccer+injuries+and+their+relation+to+physical+maturity&style=AM.+J.+DIS.+CHILD.&title=America.
- Bahr, R. & Holme, I., 2003. Risk factors for sports injuries--a methodological approach. *British journal of sports medicine*, 37(5), pp.384–92. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/14514527%5Cnhttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC1751357>.
- Barnsley, R.H., Thompson, a. H. & Legault, P., 1992. Family Planning: Football Style. The Relative Age Effect in Football. *International Review for the Sociology of Sport*, 27(1), pp.77–87.
- Baxter-Jones, A., Maffulli, N. & Helms, P., 1993. Low injury rates in elite athletes. *Archives of disease in childhood*, 68(1), pp.130–132. Available at: <http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=med3&NEWS=N&AN=8434997>.
- Bergeron, M.F. et al., 2015. International Olympic Committee consensus statement on youth athletic development. , pp.843–851.
- Biddle, S.J.H. & Asare, M., 2011. Physical activity and mental health in children and adolescents: a review of reviews. *British journal of sports medicine*, 45(11), pp.886–895.
- Bizzini, M. & Dvorak, J., 2015. FIFA 11+: an effective programme to prevent football injuries in various player groups worldwide—a narrative review. *Br J Sports Med*, 49(January), pp.577–579.

- Bizzini, M., Junge, A. & Dvorak, J., 2013. Implementation of the FIFA 11+ football warm up program: How to approach and convince the Football associations to invest in prevention. *Br J Sports Med*, 47(12), pp.803–6. Available at: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3717809&tool=pmc-entrez&rendertype=abstract>.
- Blake, C. et al., 2014. Epidemiology of injuries in hurling: a prospective study 2007–2011. *BMJ open*, 4(6), p.e005059. Available at: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=4067887&tool=pmc-entrez&rendertype=abstract>.
- Bleakley, C., Tully, M. & O’Connor, S., 2011. Epidemiology of Adolescent Rugby Injuries: A Systematic Review. *J Athl Train*, 46(5), pp.555–565.
- Bloomfield, J., Polman, R. & O’Donoghue, P., 2007. Physical demands of different positions in FA Premier League soccer. *Journal of Sports Science and Medicine*, 6(1), pp.63–70.
- Bolonchuk, W.W. et al., 2000. Association of dominant somatotype of men with body structure, function during exercise, and nutritional assessment. *American journal of human biology : the official journal of the Human Biology Council*, 12(2), pp.167–180. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11534013>.
- Breda, I.P., 2016. 2016 FIFA Activity Report. The Year in Review, 67th FIFA Congress, (April), pp.1–2.
- Brenner, J.S., 2007. Overuse injuries, overtraining, and burnout in child and adolescent athletes. *Pediatrics*, 119(6), pp.1242–1245.
- Brooks, J.H.M. et al., 2005. Epidemiology of injuries in English professional rugby union: part 1 match injuries. *British journal of sports medicine*, 39(10), pp.757–66. Available at: <http://bjsm.bmj.com/content/39/10/757>.
- Butler, R.J. et al., 2013. Modifiable risk factors predict injuries in firefighters during training academies. *Work*, 46(1), pp.11–17.
- Caine, D. & Goodwin, B.J., 2015. Risk factors for injury in pediatric and adolescent sports. In *Injury in Pediatric and Adolescent Sports: Epidemiology, Treatment and Prevention*. pp. 191–203.
- Caine, D., Maffulli, N. & Caine, C., 2008. Epidemiology of Injury in Child and Adolescent Sports: Injury Rates, Risk Factors, and Prevention. *Clinics in Sports Medicine*, 27(1), pp.19–50.
- Caine, D., Purcell, L. & Maffulli, N., 2014. The child and adolescent athlete: a review of three potentially serious injuries. *BMC Sports Science, Medicine and Rehabilitation*, 6(1), p.22. Available at: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=4055241&tool=pmc-entrez&rendertype=abstract>.
- Clarsen, B. & Bahr, R., 2014. Matching the choice of injury/illness definition to study setting, purpose and design: one size does not fit all! *British Journal of Sports Medicine*, 48(7), pp.510–512. Available at: <http://bjsm.bmj.com/lookup/doi/10.1136/bjsports-2013-093297>.
- Clement, D., Arvinen-Barrow, M. & Fetty, T., 2015. Psychosocial responses during different phases of sport-injury rehabilitation: A qualitative study. *Journal of Athletic Training*, 50(1), pp.95–104.

- Cobley, S. et al., 2009. Annual age-grouping and athlete development: A meta-analytical review of relative age effects in sport. *Sports Medicine*, 39(3), pp.235–256.
- Cromwell, F., 2000. A pilot study examining injuries in elite gaelic footballers. *British Journal of Sports Medicine*, 34(2), pp.104–108. Available at: <http://bjsm.bmj.com/cgi/content/long/34/2/104> [Accessed October 30, 2015].
- Cross, M.J., 2015. The Influence of In-Season Training Loads on Injury Risk in Professional Rugby Union. *International journal of sports physiology and performance*, (1), pp.1–5.
- Crowley, P.J. et al., 1995. Value of wearing head protection gear while playing hurling. *British Journal of Sports Medicine*, 29(3), pp.191–193. Available at: <http://bjsm.bmj.com/cgi/doi/10.1136/bjsm.29.3.191>.
- Dawes, J., Marshall, M. & Spiteri, T., 2016. Relationship Between Pre-Season Testing Performance and Playing Time among NCAA DII Basketball Players. *Sports and Exercise Medicine - Open Journal*, 2(2), pp.47–54. Available at: <http://openventio.org/Volume2-Issue2/Relationship-Between-Pre-Season-Testing-Performance-and-Playing-Time-among-NCAA-DII-Basketball-Players-SEMOJ-2-138.pdf>.
- Dolan, P. & Connolly, J., 2009. The civilizing of hurling in Ireland. *Sport in Society*, 12(2), pp.196–211. Available at: <http://www.tandfonline.com/doi/abs/10.1080/17430430802590995>.
- Dupuy, O. et al., 2012. Reliability of heart rate measures used to assess post-exercise parasympathetic reactivation. *Clinical Physiology and Functional Imaging*, 32(4), pp.296–304.
- Edwards, A.M. et al., 2007. Influence of moderate dehydration on soccer performance: physiological responses to 45 min of outdoor match-play and the immediate subsequent performance of sport-specific and mental concentration tests. *British journal of sports medicine*, 41(6), pp.385–91. Available at: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2465308&tool=pmc-entrez&rendertype=abstract>.
- Ekegren, C.L., Gabbe, B.J. & Finch, C.F., 2014. Injury reporting via SMS text messaging in community sport. *Br J Sports Med*, 20(4), pp.266–71. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/24620123%5Cnhttp://bjsm.bmj.com/content/48/7/590.1.full.pdf>.
- Ekegren, C.L., Gabbe, B.J. & Finch, C.F., 2015. Injury surveillance in community sport: Can we obtain valid data from sports trainers? *Scandinavian Journal of Medicine and Science in Sports*, 25(3), pp.315–322.
- Ekegren, C.L., Gabbe, B.J. & Finch, C.F., 2015. Sports Injury Surveillance Systems: A Review of Methods and Data Quality. *Sports Medicine*, (October). Available at: <http://link.springer.com/10.1007/s40279-015-0410-z>.
- Ekstrand, J. & Gillquist, J., 1983. Soccer injuries and their mechanisms: a prospective study. *Medicine and science in sports and exercise*, 15(3), pp.267–270.
- Emery, C.A., 2003. Risk factors for injury in child and adolescent sport: a systematic review of the literature. *Clinical journal of sport medicine*, 13(4), pp.256–268.

- Emery, C. a & Meeuwisse, W.H., 2006. Injury Rates, Risk Factors, and Mechanisms of Injury in Minor Hockey. *The American Journal of Sports Medicine*, 34(12), pp.1960–1969. Available at: <http://journal.ajsm.org/cgi/doi/10.1177/0363546506290061>.
- Emery, C., Meeuwisse, W. & Hartmann, S., 2005. Evaluation of risk factors for injury in adolescent soccer. *The American Journal of Sports Medicine*, 33, pp.1882–1891. Available at: <http://ajsm.highwire.org/cgi/content/full/33/12/1882>.
- Engquist, K.D. et al., 2015. Performance Comparison of Student-Athletes and General College Students on the Functional Movement Screen and the Y Balance Test. *Journal of Strength & Conditioning Research (Lippincott Williams & Wilkins)*, 29(8), pp.2296–2303.
- Ezzat, a, Schneeberg, a & Koehoorn, M., 2014. Weighty problems: sport injuries in overweight or obese active canadian adolescents. *British journal of sports medicine*, 48(7), p.592. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/24620128>.
- Falvey, É. et al., 2013. Risk factors for hand injury in hurling: a cross-sectional study. *BMJ Open*, 3(5), p.e002634. Available at: <http://bmjopen.bmj.com/lookup/doi/10.1136/bmjopen-2013-002634>.
- Farnan, D. et al., 2013. A 3-month prospective study of injuries in amateur rugby and soccer. *Physiotherapy Practice and Research*, 34(2), pp.103–112.
- Faude, O., Rößler, R. & Junge, A., 2013. Football injuries in children and adolescent players: Are there clues for prevention? *Sports Medicine*, 43(9), pp.819–837.
- Ferguson, B. & Stern, P.J., 2014. A case of early sports specialization in an adolescent athlete. *The Journal of the Canadian Chiropractic Association*, 58(4), pp.377–83. Available at: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=4262816&tool=pmc-entrez&rendertype=abstract>.
- Finch, C., 2006. A new framework for research leading to sports injury prevention. *Journal of Science and Medicine in Sport*, 9(1–2), pp.3–9.
- Finch, C., Lloyd, D. & Elliott, B., 2009. The Preventing Australian Football Injuries with Exercise (PAFIX) Study: a group randomised controlled trial. *Injury Prevention*, 15(3), pp.e1–e1. Available at: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2684655&tool=pmc-entrez&rendertype=abstract>.
- Finch, C.F., 2011. No longer lost in translation: the art and science of sports injury prevention implementation research. *Br J Sports Med*, 45(16), pp.1253–1257.
- Finch, C.F. et al., 2015. Preventing Australian football injuries with a targeted neuromuscular control exercise programme: comparative injury rates from a training intervention delivered in a clustered randomised controlled trial. *Injury Prevention*, p.injuryprev-2015-041667. Available at: <http://injuryprevention.bmj.com/lookup/doi/10.1136/injuryprev-2015-041667>.
- Finch, C.F. et al., 2011. Towards a national sports safety strategy: addressing facilitators and barriers towards safety guideline uptake. *Injury prevention : journal of the International Society for Child and Adolescent Injury Prevention*, 17(3), p.e4.

- Focke, A. et al., 2013. Effects of age, sex and activity level on counter-movement jump performance in children and adolescents. *European Journal of Sport Science*, 13(5), pp.518–526. Available at: <http://www.tandfonline.com/doi/abs/10.1080/17461391.2012.756069>.
- Fortington, L. V. et al., 2014. When “just doing it” is not enough: Assessing the fidelity of player performance of an injury prevention exercise program. *Journal of Science and Medicine in Sport*, 18(3), pp.272–277. Available at: <http://dx.doi.org/10.1016/j.jsams.2014.05.001>.
- Foster, C. et al., 2001a. A new approach to monitoring exercise training. *Journal of strength and conditioning research*, 15(1), pp.109–15. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11708692>.
- Foster, C. et al., 2001b. A new approach to monitoring exercise training. *Journal of strength and conditioning research / National Strength & Conditioning Association*, 15(1), pp.109–15. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/11708692>.
- Foster, C., Rodriguez-Marroyo, J.A. & de Koning, J.J., 2017. Monitoring Training Loads: The Past, the Present, and the Future. *International Journal of Sports Physiology and Performance*, pp.1–24. Available at: <http://journals.humankinetics.com/doi/10.1123/ijsp.2016-0388>.
- Fraser-Thomas, J., C?tt??, J. & Deakin, J., 2008. Understanding dropout and prolonged engagement in adolescent competitive sport. *Psychology of Sport and Exercise*, 9(5), pp.645–662.
- Fuller, C.W., 2006. Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. *British Journal of Sports Medicine*, 40(3), pp.193–201.
- GAA, 2016. *An Chomhdháil Bhliantúil 2016, Annual Congress*.
- GAA, 2015. *Chomhdháil Bhliantúil 2015 Annual Congress*,
- GAA, 2012. Official Guide - Part 2. *Gaelic Athletic Association: Official Guide Part2*, (June), p.4.
- Gabbett, T.J., 2004. Influence of training and match intensity on injuries in rugby league. *Journal of sports sciences*, 22(5), pp.409–17. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15518299><http://www.tandfonline.com/doi/abs/10.1080/02640410310001641638><http://www.ncbi.nlm.nih.gov/pubmed/15160594>.
- Gabbett, T.J., 2004. Reductions in pre-season training loads reduce training injury rates in rugby league players. *British journal of sports medicine*, 38(6), pp.743–749.
- Gabbett, T.J., 2012. Sprinting Patterns of National Rugby League Competition. *Journal of Strength and Conditioning Research*, 26(1), pp.121–130.
- Gabbett, T.J., 2016. The training-injury prevention paradox: should athletes be training smarter and harder? *British Journal of Sports Medicine*, pp.1–9.
- Gabbett, T.J., Kelly, J.N. & Sheppard, J.M., 2008. Speed, change of direction speed, and reactive agility of rugby league players. *Journal of strength and conditioning research / National Strength & Conditioning Association*, 22(1), pp.174–181.
- Le Gall, F., Carling, C. & Reilly, T., 2007. Biological maturity and injury in elite youth football. *Scandinavian Journal of Medicine and Science in Sports*, 17(5), pp.564–572.

- Garrick, J.G., 2004. Preparticipation orthopedic screening evaluation. *Clin J Sport Med*, 14(3), pp.123–126.
- Gilchrist, J. et al., 2008. A randomized controlled trial to prevent noncontact anterior cruciate ligament injury in female collegiate soccer players. *The American journal of sports medicine*, 36(8), pp.1476–1483.
- Gonell, A.C., Romero, J.A.P. & Soler, L.M., 2015. RELATIONSHIP BETWEEN THE Y BALANCE TEST SCORES AND SOFT TISSUE INJURY INCIDENCE IN A SOCCER TEAM. *International journal of sports physical therapy*, 10(7), pp.955–66. Available at: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=4675196&tool=pmc-entrez&rendertype=abstract>.
- Gordon, R.E., Kassier, S.M. & Biggs, C., 2015. Hydration status and fluid intake of urban, underprivileged South African male adolescent soccer players during training. *Journal of the International Society of Sports Nutrition*, 12, p.21. Available at: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=4451871&tool=pmc-entrez&rendertype=abstract>.
- Grady, M.F. & Goodman, A., 2010. Common lower extremity injuries in the skeletally immature athlete. *Current Problems in Pediatric and Adolescent Health Care*, 40(7), pp.170–183.
- Grice, A., Kingsbury, S.R. & Conaghan, P.G., 2014. Nonelite exercise-related injuries: Participant reported frequency, management and perceptions of their consequences. *Scandinavian Journal of Medicine and Science in Sports*, 24(2).
- Grooms, D.R. et al., 2013. Soccer-specific warm-up and lower extremity injury rates in collegiate male soccer players. *Journal of Athletic Training*, 48(6), pp.782–789.
- Gupta, S.K., 2011. Intention-to-treat concept: A review. *Perspectives in clinical research*, 2(3), pp.109–12. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/21897887><http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC3159210>.
- Gwet, K.L., 2008. Intrarater reliability. *Wiley Encyclopedia of Clinical Trials*, 1(1), pp.1–14.
- Habelt, S. et al., 2011. Sport injuries in adolescents. *Orthopedic Reviews*, 3(2), pp.82–86.
- Hayen, A., Dennis, R.J. & Finch, C.F., 2007. Determining the intra- and inter-observer reliability of screening tools used in sports injury research. *Journal of Science and Medicine in Sport*, 10(4), pp.201–210.
- Helsen, W.F., van Winckel, J. & Williams, a M., 2005. The relative age effect in youth soccer across Europe. *Journal of sports sciences*, 23(6), pp.629–36. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/16195011>.
- Herman, K. et al., 2012. The effectiveness of neuromuscular warm-up strategies, that require no additional equipment, for preventing lower limb injuries during sports participation: a systematic review. *BMC Medicine*, 10(1), p.75. Available at: <http://bmcmedicine.biomedcentral.com/articles/10.1186/1741-7015-10-75>.
- van den Honert, R., 2012. Evidence of the relative age effect in football in Australia. *Journal of Sports Sciences*, 30(13), pp.1365–1374. Available at: <http://www.tandfonline.com/doi/abs/10.1080/02640414.2012.707329>.

- Hopker, J.G. et al., 2009. Familiarisation and reliability of sprint test indices during laboratory and field assessment. *Journal of Sports Science and Medicine*, 8(4), pp.528–532.
- Hopkins, W.G., 2006. Estimating Sample Size for Magnitude-Based Inferences. *Sportscience*, 10, pp.63–70.
- Hopkins, W.G., 2000. Measures of reliability in sports medicine and science. *Sports medicine (Auckland, N.Z.)*, 30(1), pp.1–15.
- Kalinowski, P. & Fidler, F., 2010. Interpreting Significance: The Differences Between Statistical Significance, Effect Size, and Practical Importance. *Newborn and Infant Nursing Reviews*, 10(1), pp.50–54.
- Kang, J. et al., 2013. Assessing the representativeness of Canadian Hospitals Injury Reporting and Prevention Programme (CHIRPP) sport and recreational injury data in Calgary, Canada. *International journal of injury control and safety promotion*, 20(1), pp.19–26. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/22364113>.
- Kerr, Z.Y. et al., 2016. The epidemiology of boys' youth lacrosse injuries in the 2015 season. *Injury Epidemiology*, 3(1), p.3. Available at: <http://www.injepijournal.com/content/3/1/3>.
- Knowles, S.B., Marshall, S.W. & Guskiewicz, K.M., 2006. Issues in estimating risks and rates in sports injury research. *Journal of Athletic Training*, 41(2), pp.207–215.
- Kraemer, W.J. & Newton, R.U., 2000. Training for muscular power. *Physical medicine and rehabilitation clinics of North America*, 11(2), p.341–368, vii.
- Kucera, K.L. et al., 2005. Injury history as a risk factor for incident injury in youth soccer. *British journal of sports medicine*, 39(7), p.462.
- Lee, A.J. & Garraway, W.M., 1996. Epidemiological comparison of injuries in school and senior club rugby. *British Journal of Sports Medicine*, 30(3), pp.213–217.
- Linder, M.M. et al., 1995. Incidence of adolescent injuries in junior high school football and its relationship to sexual maturity. *Clin J Sport Med*, 5(3), pp.167–170.
- Lockie, R.G. et al., 2015. A preliminary investigation into the relationship between functional movement screen scores and athletic physical performance in female team sport athletes. *Biology of Sport*, 32(1), pp.41–51.
- Lunn, P., Kelly, E. & Fitzpatrick, N., 2013. *Keeping Them in the Game: Taking Up and Dropping Out of Sport and Exercise in Ireland*,
- Malina, R.M. et al., 2006. Incidence and player risk factors for injury in youth football. *Clinical journal of sport medicine : official journal of the Canadian Academy of Sport Medicine*, 16(3), pp.214–222.
- Malone, S. et al., 2017. 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), pp.393–401.
- Mandelbaum, B.R. et al., 2005. Effectiveness of a neuromuscular and proprioceptive training program in preventing anterior cruciate ligament injuries in female athletes: 2-year follow-up. *The American journal of sports medicine*, 33(7), pp.1003–10. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15888716>.
- March, Y.E., 2009. Consolidated Financial Statements For the Year Ended. *Notes*, (October).

- Markovic, G. et al., 2004. Reliability and factorial validity of squat and countermovement jump tests. *Journal of strength and conditioning research / National Strength & Conditioning Association*, 18(3), pp.551–5. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/15320660>.
- van Mechelen, W., 1997. Sports injury surveillance systems. “One size fits all”? *Sports Med*, 24(3), pp.164–168. Available at: http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=9327530.
- van Mechelen, W., Hlobil, H. & Kemper, H.C., 1992. Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. *Sports medicine (Auckland, N.Z.)*, 14(2), pp.82–99. Available at: <http://eutils.ncbi.nlm.nih.gov/entrez/eutils/elink.fcgi?dbfrom=pubmed&id=1509229&retmode=ref&cmd=prlinks%5Cpapers3://publication/uuid/7A46738F-5221-4936-AF0B-ED2B63F934BB>.
- Meeuwisse, W.H. et al., 2007. A dynamic model of etiology in sport injury: the recursive nature of risk and causation. *Clinical journal of sport medicine : official journal of the Canadian Academy of Sport Medicine*, 17(3), pp.215–219.
- Meyer, F., O’Connor, H. & Shirreffs, S.M., 2007. Nutrition for the young athlete. *Journal of sports sciences*, 25 Suppl 1(May), pp.S73–S82.
- Milewski, M.D. et al., 2014. Chronic Lack of Sleep is Associated With Increased Sports Injuries in Adolescent Athletes. *Journal of Pediatric Orthopaedics*, 34(2), pp.129–133. Available at: <http://content.wkhealth.com/linkback/openurl?sid=WKPTLP:landingpage&an=01241398-201403000-00001>.
- Moir, G., Shastri, P. & Connaboy, C., 2008. Intersession reliability of vertical jump height in women and men. *Journal of strength and conditioning research / National Strength & Conditioning Association*, 22(6), pp.1779–1784.
- Murphy, D.F., Connolly, D. a J. & Beynon, B.D., 2003. Risk factors for lower extremity injury: a review of the literature. *British journal of sports medicine*, 37(1), pp.13–29.
- Murphy, J.C. et al., 2012. Incidence of Injury in Gaelic Football: A 4-Year Prospective Study. *The American Journal of Sports Medicine*, 40(9), pp.2113–2120.
- Murphy, J.C., Gissane, C. & Blake, C., 2012. Injury in elite county-level hurling: a prospective study. *Br J Sports Med*, 46(2), pp.138–142. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/20961917>.
- Musch, J., 2001. Unequal Competition as an Impediment to Personal Development: A Review of the Relative Age Effect in Sport. *Developmental Review*, 21, pp.147–167. Available at: <http://www.sciencedirect.com/science/article/pii/S0273229700905161>.
- Nagahara, R. et al., 2014. Kinematics of transition during human accelerated sprinting. *Biology open*, pp.1–11. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/24996923>.
- Newell, M. et al., 2006. Incidence of injury in elite Gaelic Footballers. *Irish Medical Journal*, 99(9).
- Nuzzo, J.L., Anning, J.H. & Scharfenberg, J.M., 2011. The reliability of three devices used for measuring vertical jump height. *Journal of strength and conditioning research / National Strength & Conditioning Association*, 25(9), pp.2580–2590.

- O' Connor, S. et al., 2016. Epidemiology of injury in male adolescent Gaelic games. *Journal of Science and Medicine in Sport*, 19(5), pp.384–388.
- O' Connor, S. et al., 2015. Epidemiology of injury in male adolescent Gaelic games. *Journal of science and medicine in sport / Sports Medicine Australia*, pp.2–6. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/26094165>.
- O'Brien, J. & Finch, C.F., 2014. The implementation of musculoskeletal injury-prevention exercise programmes in team ball sports: a systematic review employing the RE-AIM framework. *Sports medicine (Auckland, N.Z.)*, 44(9), pp.1305–1318.
- O'Connor, S. et al., 2016. Epidemiology of injury in male collegiate Gaelic footballers in one season. *Scandinavian Journal of Medicine and Science in Sports*, pp.1–7.
- O'Malley, E. et al., 2016. The effects of the GAA 15 training program on neuromuscular outcomes in Gaelic football and hurling players; a randomized cluster trial. *Journal of strength and conditioning research*. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/27398918>.
- O'Brien, J. & Finch, C.F., 2016. Injury prevention exercise programmes in professional youth soccer: understanding the perceptions of programme deliverers. Available at: <http://dx.doi.org/10.1136/>.
- Oliver Gonzalo-Skok, Jorge Serna, Matthew R. Rhea, P.J.M., 2015. Relationship between functional movement tests and performance test in young elite male basketball players. *The International Journal of Sports Physical Therapy*, 10(5), pp.628–638.
- Owen, A. et al., 2013. Effect of an Injury Prevention Program on Muscle Injuries in Elite Professional Soccer. *Journal of Strength and Conditioning Research*, 27(12), pp.3275–3285.
- Owoeye, O.B.A. et al., 2014. Efficacy of the FIFA 11+ warm-up programme in male youth football: A cluster randomised controlled trial. *Journal of Sports Science and Medicine*, 13(2), pp.321–328.
- Owoeye, O.B. a et al., 2014. Efficacy of the FIFA 11+ warm-up programme in male youth football: A cluster randomised controlled trial. *Journal of Sports Science and Medicine*, 13(2), pp.321–328.
- Øyen, J., Torstveit, M.K. & Sundgot-Borgen, J., 2009. Self-reported versus diagnosed stress fractures in Norwegian female elite athletes. *Journal of Sports Science and Medicine*, 8(1), pp.130–135.
- Plisky, P.J. et al., 2006. Star excursion balance test as a predictor of lower extremity injury in high school basketball players. *Journal of Orthopaedic & Sports Physical Therapy*, 36(12), pp.911–919.
- Plisky, P.J. et al., 2009. The reliability of an instrumented device for measuring components of the star excursion balance test. *North American journal of sports physical therapy : NAJSPT*, 4(2), pp.92–99.
- du Prel, J.-B. et al., 2009. Confidence interval or p-value? *Deutsches Arzteblatt international*, 106(19), pp.335–339.
- Quatman, C.E. & Hewett, T.E., 2009. The anterior cruciate ligament injury controversy: is “valgus collapse” a sex-specific mechanism? *British journal of sports medicine*, 43(5), pp.328–35. Available at: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=4003572&tool=pmc-entrez&rendertype=abstract>.

- Reilly, T. & Collins, K., 2008. Science and the Gaelic sports: Gaelic football and hurling. *European Journal of Sport Science*, 8(5), pp.231–240.
- Richmond, S.A., Kang, J. & Emery, C.A., 2013. Is body mass index a risk factor for sport injury in adolescents? *Journal of Science and Medicine in Sport*, 16(5), pp.401–405.
- Ristolainen, L. et al., 2009. Gender differences in sport injury risk and types of injuries: A retrospective twelve-month study on cross-country skiers, swimmers, long-distance runners and soccer players. *Journal of Sports Science and Medicine*, 8(3), pp.443–451.
- Roe, M. et al., 2016. Injury Scheme Claims in Gaelic Games: A Review of 2007–2014. , 51(4).
- Rogalski, B. et al., 2013. Training and game loads and injury risk in elite Australian footballers. *Journal of Science and Medicine in Sport*, 16(6), pp.499–503.
- Root, H. et al., 2015. Landing technique and performance in youth athletes after a single injury-prevention program session. *Journal of Athletic Training*, 50(11), pp.1149–1157.
- Rose, M.S., Emery, C.A. & Meeuwisse, W.H., 2008. Sociodemographic predictors of sport injury in adolescents. *Medicine and Science in Sports and Exercise*, 40(3), pp.444–450.
- Rumpf, M.C. et al., 2011. Assessing youth sprint ability-methodological issues, reliability and performance data. *Pediatric exercise science*, 23(4), pp.442–67. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/22109773>.
- Runyan, C.W., 1998. Using the Haddon matrix: introducing the third dimension. *Injury Prevention*, 4(4), pp.302–307. Available at: <http://injuryprevention.bmj.com/content/4/4/302.short>.
- Sallis, R.E. et al., 2001. Comparing sports injuries in men and women. *International Journal of Sports Medicine*, 22(6), pp.420–423.
- Saw, A.E., Main, L.C. & Gatin, P.B., 2015. Role of a Self-report Measure in Athlete Preparation. *Journal of Strength and Conditioning Research*, 29(3), pp.685–691. Available at: http://journals.lww.com/nsca-jscr/Abstract/publishahead/The_role_of_a_self_report_measure_in_athlete.97221.aspx%5Cnhttp://www.ncbi.nlm.nih.gov/pubmed/25226334%5Cnhttp://content.wkhealth.com/linkback/openurl?sid=WKPTLP:landingpage&an=00124278-201503000-00015.
- Scase, E. et al., 2012. The epidemiology of injury for an elite junior Australian Football cohort. *Journal of Science and Medicine in Sport*, 15(3), pp.207–212.
- Sedgwick, P., 2014. Clinical significance versus statistical significance. *Bmj*, 348(mar14 11), pp.g2130–g2130. Available at: <http://www.bmj.com/cgi/doi/10.1136/bmj.g2130>.
- Shaffer, S.W. et al., 2013. Y-balance test: a reliability study involving multiple raters. *Military medicine*, 178(11), pp.1264–70. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/24183777>.
- Shirreffs, S.M. & Sawka, M.N., 2011. Fluid and electrolyte needs for training, competition, and recovery. *Journal of Sports Sciences*, 29(sup1), pp.S39–S46.

- Silvers-Granelli, H. et al., 2015. Efficacy of the FIFA 11+ Injury Prevention Program in the Collegiate Male Soccer Player. *The American journal of sports medicine*, 43(11), pp.2628–37. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/26378030>.
- Silvers, H. et al., 2014. the Efficacy of the Fifa 11+ Program in the Collegiate Male Soccer Player (Usa). *British Journal of Sports Medicine*, 48(7), pp.662–662. Available at: <http://bjsm.bmj.com/cgi/doi/10.1136/bjsports-2014-093494.272>.
- Slinde, F. et al., 2008. Test-retest reliability of three different countermovement jumping tests. *Journal of strength and conditioning research / National Strength & Conditioning Association*, 22(2), pp.640–644.
- Smith, J.W., Holmes, M.E. & McAllister, M.J., 2015. Nutritional Considerations for Performance in Young Athletes. *Journal of sports medicine (Hindawi Publishing Corporation)*, 2015, p.734649. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/26464898><http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC4590906>.
- Soligard, T. et al., 2008. Comprehensive warm-up programme to prevent injuries in young female footballers: cluster randomised controlled trial. *BMJ*, 337(dec09 2), pp.a2469–a2469. Available at: <http://www.bmj.com/cgi/doi/10.1136/bmj.a2469>.
- Soprano, J. V. & Fuchs, S.M., 2007. Common Overuse Injuries in the Pediatric and Adolescent Athlete. *Clinical Pediatric Emergency Medicine*, 8(1), pp.7–14.
- Steffen, K. et al., 2013. High adherence to a neuromuscular injury prevention programme (FIFA 11+) improves functional balance and reduces injury risk in Canadian youth female football players: a cluster randomised trial. *British journal of sports medicine*, 47(12), pp.794–802. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/23559666>.
- Stevenson, J.H. et al., 2014. Assessing the Effectiveness of Neuromuscular Training Programs in Reducing the Incidence of Anterior Cruciate Ligament Injuries in Female Athletes: A Systematic Review. *The American Journal of Sports Medicine*, pp.1–9. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/24569703>.
- Straccolini, A. et al., 2016. The Relative Age Effect on Youth Sports Injuries. *Medicine and Science in Sports and Exercise*.
- Stubbe, J.H. et al., 2015. Injuries in professional male soccer players in the Netherlands: A prospective cohort study. *Journal of Athletic Training*, 50(2), pp.211–216.
- Taylor, K.-L. et al., 2012. Fatigue Monitoring in High Performance Sport: a Survey of Current Trends. *Journal of Australian Strength and Conditioning*, 20(1), pp.12–23.
- Taylor, M.J.D. et al., 2010. Vertical jumping and leg power normative data for English school children aged 10-15 years. *Journal of sports sciences*, 28(8), pp.867–872.
- Theisen, D. et al., 2013a. Injury risk is different in team and individual youth sport. *Journal of Science and Medicine in Sport*, 16(3), pp.200–204. Available at: <http://dx.doi.org/10.1016/j.jsams.2012.07.007>.
- Theisen, D. et al., 2013b. Injury risk is different in team and individual youth sport. *Journal of Science and Medicine in Sport*, 16(3), pp.200–204.

- Thorborg, K. et al., 2017. Effect of specific exercise-based football injury prevention programmes on the overall injury rate in football: a systematic review and meta-analysis of the FIFA 11 and 11+ programmes. *British Journal of Sports Medicine*, p.bjsports-2016-097066. Available at: <http://bjsm.bmj.com/lookup/doi/10.1136/bjsports-2016-097066>.
- Tomáš, M. et al., 2014. Profile, correlation and structure of speed in youth elite soccer players. *Journal of human kinetics*, 40, pp.149–59. Available at: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=4096104&tool=pmc-entrez&rendertype=abstract>.
- Vanderlei, F.M. et al., 2014. Characteristics and associated factors with sports injuries among children and adolescents. *Brazilian Journal of Physical Therapy / Revista Brasileira de Fisioterapia*, 18(6), pp.530–537. Available at: <http://search.ebscohost.com/login.aspx?direct=true&AuthType=ip,shib&db=s3h&AN=100672776&site=ehost-live&scope=site>.
- Vgontzas, A.N. et al., 2004. Adverse Effects of Modest Sleep Restriction on Sleepiness, Performance, and Inflammatory Cytokines. *Journal of Clinical Endocrinology and Metabolism*, 89(5), pp.2119–2126.
- Waldén, M. et al., 2012. Prevention of acute knee injuries in adolescent female football players: cluster randomised controlled trial. *BMJ (Clinical research ed.)*, 344, p.e3042. Available at: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3342926&tool=pmc-entrez&rendertype=abstract>.
- Walker, S., 2013. Mindfulness and burnout among competitive adolescent tennis players. *South African Journal of Sports Medicine*, 25(4), pp.105–108. Available at: <http://www.ajol.info/index.php/sasma/article/view/98463>.
- Walker, S. & Turner, A., 2009. A One-Day Field Test Battery for the Assessment of Aerobic Capacity, Anaerobic Capacity, Speed, and Agility of Soccer Players. *Strength and Conditioning Journal*, 31(6), pp.52–60.
- Warburton, D.E.R., Nicol, C.W. & Bredin, S.S.D., 2006. Health benefits of physical activity: the evidence. *Canadian Medical Association Journal*, 174(6), pp.801–809.
- Wattie, N. et al., 2007. Injuries in Canadian youth ice hockey: the influence of relative age. *Pediatrics*, 120(1), pp.142–8. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17606571>.
- Weaver, N.L., Marshall, S.W. & Miller, M.D., 2002. Preventing sports injuries: Opportunities for intervention in youth athletics. *Patient Education and Counseling*, 46(3), pp.199–204.
- Weeks, B.K., Carty, C.P. & Horan, S.A., 2012. Kinematic predictors of single-leg squat performance: a comparison of experienced physiotherapists and student physiotherapists. *BMC musculoskeletal disorders*, 13, p.207. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/23098061> <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC3517427>.
- Wolf, B.R. et al., 2009. Injury patterns in Division I collegiate swimming. *The American journal of sports medicine*, 37(10), pp.2037–42. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/19633232> <http://ajs.sagepub.com/content/37/10/2037.short>.

- World Health Organization, 2015. Global Recommendations on Physical Activity for Health. Available at: <http://www.who.int/mediacentre/factsheets/fs385/en/> [Accessed March 14, 2016].
- Yard, E.E. et al., 2008. The epidemiology of United States high school soccer injuries, 2005-2007. *The American journal of sports medicine*, 36(10), pp.1930–1937.

Appendices

Appendix A – Participant Consent Form



Consent Form

Dear Sir/Madam

Your son has been selected to participate in a research study titled –

‘A Study to Evaluate the Effects of a Neuromuscular Injury Prevention Programme (GAA15) in Adolescent Males participating in Hurling’.

- The GAA’s commitment to optimal player welfare is a priority to facilitate a long and healthy player pathway from underage to adulthood. This successful pathway has multiple benefits both individually to the player but also to their families and the community. It is accepted that participation in sports, at all levels, contributes to a healthy mental and physical state. Adolescents are vulnerable in terms of overload and growth related injuries in sport, and Gaelic games are no exception to this.
- The focus of this research project is to assess and critically analyse the application and implementation of a neuromuscular injury prevention program (warm-up) to age 13-18-year-old boys participating in GAA at post primary level.
- The study will be supervised by lead researcher Seán Kelly BSc (Hons) Sport Science and Dr Clare Lodge BSc (Hons) Physiotherapy, MSc Sports Medicine, Department of Science and Health, Institute of Technology Carlow.
- Prior to the commencement of the programme your son will undergo a screening process to assess and provide a baseline of their neuromuscular function and physical performance measures. The same tests will be implemented at the end of the experimental eight-week period to determine the effect of the programme on these measures.
- Throughout the study all subjects will be required to perform a neuromuscular injury prevention program on a regular basis. This program will take the form of a ‘sport-specific’ warm-up prior to each team training session and on match days.

The warm-up will be designed to target and improve the physical aspects of performance related to higher risk of injury.

- A wellness side to the study will be completed daily by the subjects via a Smartabase phone application used to log daily activities and injury incidences.

Your confidentiality will be guarded. IT Carlow will protect the information about you and your part in this study and no names or identifying data will be published and full anonymity will be ensured. This will be achieved by assigning your son an ID number against which all data will be stored. Details linking your ID number and name will not be stored with the data. The results of the study maybe published and used in further studies.

If you have any questions about the study, we are free to contact at –

- Dr. Clare Lodge Tel: 059 9175520
- Email: Claire.Lodge@itcarlow.ie

- Seán Kelly Tel: 086 2595472
- Email: Sean.Kelly@itcarlow.ie

Taking part in this study is my decision. If I do agree to take part, I may withdraw at any point including during the exercise test. There will be no penalty if I withdraw before I have completed all stages of the study.

(Print name of student) _____

(Print school name) _____ has permission to take part in this study.

Parents Signature _____

Mobile No. _____

Parents Email: _____

Students Signature _____

Mobile No. _____ DOB _____

Appendix B – Ethics Application Form



APPLICATION FOR ETHICAL CLEARANCE FOR A RESEARCH PROJECT (FORM REC2-L9(R)/ L10)

Completing Forms

When filling in applications for exemption or for ethical review please ensure that:

- All relevant sections are completed in typed text;
- All responses are placed within the spaces allocated;
- Bold type is not used;
- All sections are completed. Where a section or a question is not relevant to the proposed research project this should be indicated by entering N/A in the relevant section. Sections should not be left blank;
- Applicants shall ensure that responses to questions are not cross referenced to previous answers on the form. For example an answer which states “see above” or “see answer to question 3” is not an adequate response and a form bearing such a response shall be returned for satisfactory completion.
- Jargon or unexplained abbreviation is not used;
- All technical terms are explained in clear terms;
- All technical procedures are adequately described to enable assessors to determine the ethical implications of the proposed research project.

Application for ethical review exemption or for ethical clearance is an essential element in any research project. It represents a clear articulation of the research project, its methods, aims, objectives and outputs. Completed forms should be submitted (in the first instant) to the Head of Department or School (or a designated staff member) for initial screening and endorsement. Forms which have not been completed satisfactorily or which are unclear or ambiguous shall be returned and shall not be tabled before the Ethics Committee for consideration.

**Application to the IT Carlow Research Ethics Committee for
Ethical Approval of a Research Project involving Human Participants or
samples donated by Human Participants (e.g. tissue or blood samples)
(FORM REC2-L9(R)/ L10)**

**Applicants are advised to submit any supporting documentation they may
feel is relevant to their research proposal (e.g. sample interview schedules,
consent forms, third party licenses or ethical approvals).**

A. Applicant Details

A.1 Researcher Details:

Name: Seán Kelly
Email: Sean.Kelly@itcarlow.ie
Telephone: 086 2595472

A.2 Principal Investigator / Research Supervisor(s):

Name: Dr. Clare Lodge
Email: Claire.Lodge@itcarlow.ie
Telephone: 086 8322527

A.3 Additional Expertise (if applicable)

Name: _____
Email: _____
Telephone: _____

A.4 Does this research form part of a programme of study?

Yes No

If yes – please give details

It is part of the Presidents Research Fellowship Programme 2015-2017

- A.5 I confirm that I have read and understood the following IT Carlow Policies:
- | | | |
|--------------------------------------|---|-----------------------------|
| Ethics Policy | <input checked="" type="checkbox"/> Yes | <input type="checkbox"/> No |
| Ethics Procedures and Guidance notes | | |
| On completing this form | <input checked="" type="checkbox"/> Yes | <input type="checkbox"/> No |
| Data Protection Policy | <input checked="" type="checkbox"/> Yes | <input type="checkbox"/> No |
| Anti-Plagiarism Policy | <input checked="" type="checkbox"/> Yes | <input type="checkbox"/> No |

B. Research Proposal

B.1 Title of the proposed research project

A Study to Evaluate the Effects of a Neuromuscular Injury Prevention Programme in Post Primary School Adolescent Males participating in Hurling.

B.2 To what extent has this topic already been researched and written about (e.g. is there a significant body of existing published work)?

This will be the first research of this kind in Ireland. Other countries are leading the way in prophylaxis in this population group. The Canadian Academy of Sports and Exercise Medicine (CASEM) in response to the growing prevalence of Anterior Cruciate Ligament (ACL) injuries in the adolescent population developed a national program.

Youth Rugby in the UK concur with the Canadian philosophy. An epidemiological study executed over two seasons in youth academy versus schools rugby (ages 16-18 yrs.) identified that lower extremity injuries were the most prevalent. They concluded that a national prevention strategy was warranted to decrease the incidence and prevalence of these injuries and also to address the identified risks contributing to the injuries.

Finally Sweden in 2012 published data on 4500 female soccer players who participated in a study to assess prevention strategies aimed at decreasing lower extremity injury incidence with promising results. Those that participated in the intervention group namely the “knee control program” decreased the incidence of ACL injuries by 2/3, while those in the control group sustained 50% more serious knee injuries than their intervention counterparts.

B.3 From that, describe how this proposed research is contributing to what is known about the topic

The evidence is convincing and highlights the urgency to optimise movement patterns, particular to a given sport, which will optimise performance and reportedly decrease the incidence of injury. Piloting of this in the adolescent post primary population would be the optimal cohort. It is well documented that motor programming at a younger age is correlated with optimal movement patterning and can be easily modified and sustained. A proactive approach has been established in the international studies discussed with the emphasis on education

strategies aimed at improving mechanics and thereby reducing the identified potential risk factors to injury.

B.4 Provide a brief description of research (*not more than 200 words in any section*)

a) The aims and objectives

The main purpose is to determine if a neuromuscular injury prevention programme will help to reduce non-contact injuries in adolescent males. The focus of this research project is to assess and critically analyse the application and implementation of a neuromuscular injury prevention program (sport specific warm-up) to age 13-18 year old boys participating in hurling at post primary level. Concurrently lower extremity injury incidence throughout the same time period will be closely monitored by a self-monitoring phone application system "Smartabase", with potential modifiable risk factors for injury being identified.

b) The research design

(Note: This section can include an overview of methodology research design proposals regarding for example, evaluation and data gathering. In describing the research design, applicants are required to explain the reasoning behind their choice of method)

Six post primary schools in County Kilkenny will be included in the study (the Intervention group)

1. Castlecomer Community School,
2. Colaiste Mhuire, Johnstown,
3. St. Kieran's College,
4. Scoil Aireagail,
5. Colaiste Eamann Rís,
6. CBS Kilkenny

Male subjects from two hurling teams, junior (under 14½ years) and senior (under 18 ½ years) from each school will take part, providing in the region of 350-400 participants. A control group (350-400 participants) will be set up in six post primary schools outside of County Kilkenny that will concurrently record incidence of injury and time lost from play and training over the same time period.

Stage 1:

The researcher will invite all school team trainers, coaches and managers to a workshop where they will be briefed and educated on the purpose of the study with supporting data through a workshop format. They will be educated on the prevention intervention components that will be integrated into their training sessions as part of the warm-up process pre training and pre match and will be requested to keep a log of compliance at the end of each week of training through the coaches Smartabase phone application. Each coach will receive a dvd of the proposed intervention warm-up along with a printed hard copy of the layout and timing of the warm-up structure and routine.

The researcher will then hold a workshop training day for each of the school teams involved in the study where the subjects will be educated on the setup and use of the phone application and the details of the study. A wellness side to the study will be completed daily by the subjects via the Smartabase phone application used to log daily activities and injury incidences.

Stage 2:

Prior to the commencement of the intervention programme each player will undergo a screening process to assess and provide a baseline of their neuromuscular function and physical performance measures. The same tests will be implemented at the end of an eight week period to determine the effect of the programme on these measures. It will be completed a third time at the end of the experimental period which is the whole duration of the season until they are knocked out of their championship.

The performance measures:

- 10meter acceleration and 20meter speed tests
- Standing vertical jump test
- Y-Balance test

The researcher will liaise with the individual team trainers and attend one session to teach the intervention programme (warm-up). The researcher will be responsible for liaising with the team trainers, logging injuries / time lost from participation on a weekly basis and initially planning and providing the educational workshops.

Stage 3:

Qualitative methodologies will also be used to gain deeper insights into the practical implementation of this study. Semi structured interviews to the teacher / coaches and trainers will be conducted to gain a better understanding of the practicalities of implementation, this will provide further insight into the future of post primary GAA support. Semi structured interviews will be conducted on one player from each of the teams to gain a deeper insight into the recipients views with respect to practicalities, timing, compliance and reception into the training session. The purpose of this study is to assess strategies that i) identify injury risk and ii) prevent or decrease the risk of injury in order to promote optimal health and player wellbeing in post primary GAA

c) The size and composition of sample

It is proposed that 700-800 subjects will participate in this research study.

Two groups of subjects will take part,

1. The intervention group consisting of 350-400 subjects, and
2. The control group consisting of 350-400 subjects.

d) The method of how participants are expected to be selected, approached and recruited in conducting this proposed research?

(Note: The process of participant selection is required to be outlined clearly. If for example, participants are being contacted through an organisation, e.g. school, an initial step would be to seek permission from the organisation to approach the participants. Any inclusion or exclusion criteria must also be specified.

All subjects will be contacted through their schools as part of a school team.

1. An email is sent to the school hurling team manager/coach, outlining the research study and looking for a meeting.
2. During this meeting the full details of the research is explained and a copy of the study overview is presented to them with consent forms for the participating players.
3. The school hurling team manager will speak to his players and explain what is involved in the research and offer consent forms to those that have an interest in being involved in the research.
4. All players wishing to take part in the research study must return the consent forms signed by a parent or guardian.
5. Once the consent forms are returned to the school, a players list is provided by the school, so that username and passwords can be set up for the mobile phone app.

- e) Describe the procedures that will be adopted to maintain the confidentiality of research subject(s).

Confidentiality will be guarded. IT Carlow will protect the information about each subject and their part in this study and no names or identifying data will be published with full anonymity being ensured. This will be achieved by assigning each subject an ID number against which all data will be stored. Details linking each ID number and name will not be stored with the data. The subjects involved will be made aware that the results of the study maybe published and used in further studies.

- f) Will any member of the intended group of research subjects, to your knowledge, be involved in other research projects or activities? If so, please give details and explain the nature of the engagement with other projects.

To my knowledge, subjects involved will not be partaking in any other research projects to the detriment of the present study

- g) Describe how the information is gathered, stored, handled and anonymised.

IT Carlow will protect the information about each subject and their part in this study and no names or identifying data will be published with full anonymity being ensured. This will be achieved by assigning each subject an ID number against which all data will be stored. Details linking each ID number and name will not be stored with the data.

- h) Please state the location(s) the proposed research is to be conducted

- Institute of Technology Carlow
- Castlecomer Community School, Castlecomer, Co. Kilkenny
- Colaiste Mhuire, Johnstown, Co. Kilkenny
- St. Kieran's College, College Road, Kilkenny

- Scoil Aireagail, Ballyhale, Co. Kilkenny
- Colaiste Eamann Rís, Callan, Co. Kilkenny
- CBS Kilkenny, James Street, Kilkenny

i) The proposed starting date of research/ study

October 1st. 2015

B.5 Has this research proposal received ethical approval from any other body? – if so please provide details.

No

B.6 Does this proposed research require licensing approval? – if so please provide details of licenses obtained.

No

B.7 Describe the research procedures as they affect the research subject and any other parties involved.

Participants within the intervention group will be required to perform a neuromuscular injury prevention program on a regular basis. This program will take the form of a 'sport-specific' warm-up prior to each team training session and on match days. The warm-up will be designed to target and improve the physical aspects of performance related to higher risk of injury. These aspects are:

- Strength deficiency,
- Lack of flexibility,
- Imbalance,
- Proprioception,
- Avoiding vulnerable positions (movement optimisation)

By targeting and improving these aspects of performance it is hypothesized that the number of injuries accrued throughout a season will be reduced when compared to the control group.

Each subject – in both the intervention and the control groups - will also be required to complete a 'wellness' side to the study. This aspect requires the subjects to complete a short questionnaire online via the 'smartabase' web application on a daily basis. This questionnaire enables the researcher to track daily activity levels of the subjects and log all incidences of injury throughout the season. By tracking this information it may be possible for the researcher to establish additional 'red-flags' for injury such as training overload or fatigue/lack of sleep.

B.8 Describe (a) the ethical considerations of this proposal and (b) the steps to be taken to address these.

Ethical considerations of the study center around the wellness phone application and child protection laws. As the subjects will primarily be under

the age of 18, parental consent of each subject will be obtained prior to their inclusion in the study. All information/data obtained through the app - both online and offline - is secured according to leading industry standards such as HIPAA and PEPETA. Permission to view and access the data collected is restricted to the lead researcher and their supervisor. Complete anonymity of subjects is also guaranteed.

As is the nature with all screening and performance fitness testing, it will carry a risk of injury in performing these tests. All performance testing will be set up and supervised by the lead researcher at all times. Subjects will receive a demonstration and instruction for all tests along with all safety guidelines. Subjects can withdraw at any stage during testing if they so wish.

B.9 Describe the research procedures as they affect the research subject and any other parties involved.

All subjects within the intervention group will be required to perform a neuromuscular injury prevention program (sport specific warm-up) on a regular basis, before team training and on match days. The warm-up will be designed to target and improve the physical aspects of performance related to the higher risk of injury in this cohort. These aspects are:

- Strength deficiency,
- Lack of flexibility,
- Imbalance,
- Proprioception,
- Avoiding vulnerable positions (movement optimisation)

By targeting and improving these aspects of performance it is hypothesized that the number of injuries accrued throughout a season will be reduced when compared to the control group.

Each subject – in both the intervention and the control groups - will also be required to complete a ‘wellness’ side to the study. This aspect requires the subjects to complete a short questionnaire online via the ‘smartabase’ web application on a daily basis. This questionnaire enables the researcher to track daily activity levels of the subjects and log all incidences of injury throughout the season. By tracking this information it may be possible for the researcher to establish additional ‘red-flags’ for injury such as training overload or fatigue/lack of sleep.

B.10 Please list the investigators (including assistants) who will conduct the research. Please provide details of their qualifications and experience

Seán Kelly, BSc (Hons) Sport Science, is the lead research investigator on this project and will carry out all the research involved. Seán received an upper second class honours degree in sport science from the Institute of Technology, Carlow in 2015. He is a Level 1 GAA coach with over twenty years of coaching experience at all grades within the GAA. He is currently the strength and conditioning coach with the Kilkenny Minor (under 18 years) hurling team, a position that he has held since 2011. He is also the current manager of the IT Carlow senior ladies camogie team.

| |
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|--|

B.11 Are arrangements for the provision of clinical facilities to handle emergencies necessary? If so, briefly describe the arrangements made.

| |
|---|
| All testing and training will take place on the properties of the schools involved under the supervision of the coaches and teachers from each school. Any provisions necessary will be undertaken by the school. |
|---|

B.12 Specify whether research subjects include students or others in a dependent relationship.

| |
|---|
| Subjects involved will be aged between 13-18 years of age. Adolescent growth spurts, skeletal immaturity and training overload, make teen players very vulnerable to injuries, particularly if they are subject to poor training techniques and errors, such as mismatching groups who are not the same size or do not have the same experience. Adolescents are vulnerable in terms of overload and growth-related injuries in sport, and Gaelic games are no exception to this, with young players often playing for school, club and county, often in more than one age and, as a result, potentially exposing themselves to avoidable injuries. This research programme will set out to study this vulnerable cohort, surveying the modifiable risk factors, as well as assessing the effectiveness of specific strategies at potentially decreasing the incidence of injuries within this sporting group. As is the nature of the study, this is necessary to include these subjects in order to improve the current practices with adolescents in the GAA. |
|---|

B.13 Specify whether the research will include primary respondents such as children, individuals with mental health issues, individuals deemed to be of diminished responsibility, individuals with a physical or intellectual disability. If so, please explain the rationale for accessing these subjects for the proposed research. Please indicate alternative measures investigated to avoid the necessity for direct access to these primary respondents.

| |
|--|
| All subjects will be pupils within the respective schools involved and it is assumed they will be dependent on their parents/guardians. In this case, permissions and a signed consent form will be sought for each subject prior to their inclusion in the study. |
|--|

B.14 Please confirm that no payment will be made to any research subject

| |
|---|
| Subjects will not receive payment for completing the study. |
|---|

B.15 Describe the procedures to be used in obtaining a valid consent from the subject. Please supply a copy of the information sheet provided to the individual subject(s).

Initial contact with schools will be made through phone calls by Seán Kelly with a view to them agreeing to be involved with the project. When a school confirms their participation in the study, an email will be sent to the respective coaches/teachers outlining the methodology and practicalities of the study. This email will also contain an attached consent form and to be distributed to each of the subjects parents/guardians requesting their written consent to include their son(s) in the study.

B.16 Please indicate if there are any cultural, social, gender-based characteristics or sexual orientation, practices or behaviour of the subject(s) which have affected the design of the project or which may affect its outcomes.

N/A

Signed: _____
Researcher

Date: _____

Signed: _____

Date

**Principal Investigator
Supervisor)**

**REVIEWER COMMENT IF APPLICABLE FROM HEAD OF
DEPARTMENT/GROUP/ INSTITUTE/CENTRE**

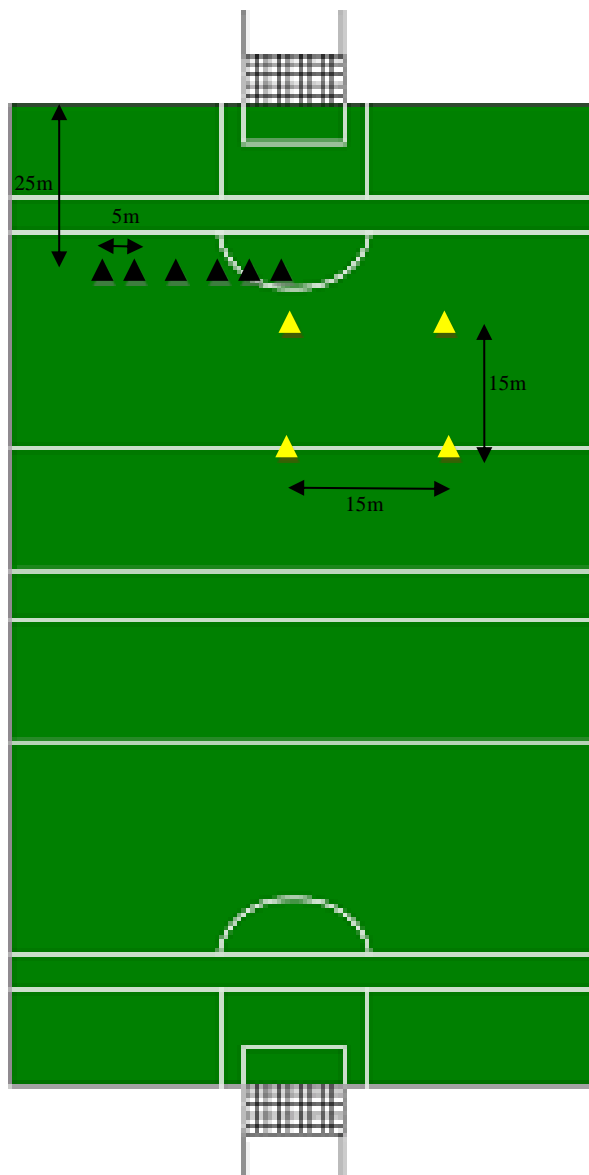
Signed: _____

Date

(Head of Department/Group/CORE/Institute/Centre)

Appendix C – GAA15 Injury prevention warm-up programme.

Field Layout



FIELD LAYOUT

Warm-Up Part 1 - All players inside 65m line

Warm-Up Part 2 (Black Cones) - A row of cones, 5m apart, 25m from end line.

Warm-Up Part 3 (Yellow Cones) - Four cones in a 15m square

Warm-Up Part 1

Raise Body Temperature (2 minutes)

- Players in groups of 3 with one sliotar.
- Players jog around inside the 65m line in any direction while striking the sliotar between the 3 players.
- Players can be any distance apart and move in any direction, jogging forward, backwards and side shuffling.
- Players must stay moving for 60 – 90 seconds.

60-90 second water break (and time for individual static stretching)

Warm-Up Part 2

Dynamic Movements, Mobility and Stretching (5 minutes)

Players in groups of 4 or 5 with 2 or 3 players at each cone 25m from end line with 2 players opposite them on end line, one sliotar per group.

1. In each group, player one (at end line) strikes the sliotar along the ground to opposite player in his group and jogs (slow pace) after the sliotar to take up new position at cone.
(20 – 30 seconds)
2. In each group, player one (at end line) solo with the sliotar on the camán (slow pace) and hand passes the sliotar to the opposite player in his group and takes up his new position.
(20 – 30 seconds)
3. In each group, player one takes two steps with the sliotar in hand and strikes the sliotar (head high) to the opposite player in his group. After striking the sliotar, the player runs with high knees to new position. Players need to slow down the pace and concentrate on proper movement mechanics, high knee lift and proper arm movement.
(20 seconds)
4. In each group, player one takes two steps with the sliotar in hand and strikes the sliotar (head high) to the opposite player in his group. After striking the sliotar, the player runs with heel flicks to new position. Players need to slow down the pace and concentrate on proper movement mechanics, high heel lift and proper arm movement.
(20 seconds).
5. All players complete a dynamic calf stretch. Players in press-up position and dynamically lower alternative heels to ground in a marching movement. (20 seconds). Reset groups.
6. All players complete leg balance, hip mobilisation into a forward lunge with left and right rotation. Players lift one knee out to the side, bring knee around to the front and step forward into a lunge while reaching up over their heads with

two hands on the hurl, next, rotate left and right with the hurl at shoulder height. Continue forward to opposite cone position of their group.

7. In each group, player one takes two steps with the sliotar in hand and strikes the sliotar low and hard into the ground in front of the opposite player in his group. After striking the sliotar, the pace of the run to the opposite side should increase. (20 - 30 seconds)
8. All players complete leg balance, hip mobilization into a reverse lunge with left and right rotation. Players lift one knee in front, bring knee around to the side and step backwards into a reverse lunge while reaching up over their heads with two hands on the camán, next, rotate left and right with the camán at shoulder height. Continue backwards to opposite position in their group.

30 second water break

Warm-Up Part 3

Movement Speed, Agility, Plyometrics, Proprioception and Strength. (3 minutes)

All players inside 4 cones (15m square) with sliotars on the ground scattered throughout the square.

1. All players move at pace throughout the square (different movements, different directions). Players jab lift the nearest sliotar, catch it in hand and plant one foot (load) on the ground and cut (side step, unload) to opposite direction and drop the sliotar. Players to cut on opposite leg each time they jab lift the sliotar. (30 seconds)
2. All players perform single leg balance into an RDL (Romanian Dead Lift). Two hands on camán and raise above head with straight arms. Knee to be raised in front before start of movement. Players to complete 5 repetitions on one leg without raised foot touching the ground.
3. All players move at pace throughout the square (different movements, different directions). Players roll lift the nearest sliotar, catch it in hand and swivel 180°, plant one foot on the ground and drop the sliotar. Players to turn off opposite leg each time they roll lift the sliotar. (30 seconds)
4. RDL on opposite leg (as per no.2 above)
5. All players move at pace throughout the square (different movements, different directions) hand passing the sliotar to other players moving throughout the square. Players to focus on proper movement and agility and increase pace. (20 seconds)
6. All players to complete five body weight squats, pause and into explosive vertical jumps. Players to focus on proper squatting and landing technique. Two hands on camán placed in front of body at shoulder height.
7. All players move throughout the square (different movements, different directions) while throwing a sliotar high in the air for another player to jump to catch the ball by using one leg to power off (jump) and land on that same leg.

Players to use different leg each time to jump for the ball. Players to focus on proper landing technique.
(30 seconds)

30 second water break

Final Part of Warm-Up

Strength, Flexibility, Movement and Speed. (2 minutes)

1. Divide players into four equal groups and each group to the yellow cones (see field layout). Players at each corner of the square to solo (at sprinting speed) diagonally with a sliotar and hand pass to the opposite player who completes the same run in the opposite direction.
(20 seconds at max pace)
2. All players to complete five inchworm (pike walk) exercises followed by one press-up and trunk rotation. Players to focus on proper technique and increasing flexibility.
3. Divide players into four equal groups and each group to the yellow cones. Players at each corner of the square to solo (at sprinting speed) diagonally with a sliotar and hand pass to the opposite player who completes the same run in the opposite direction.
(20 seconds at max pace)

Warm-up complete, players time to take a water break, complete shooting practice at goal, frees, side line cuts etc. before starting training or match.

Training and Match day warm-up should take between 12 – 15 minutes to complete.

Appendix D - Warm-up structure prior to performance testing.

1. Participants jogging at slow pace inside a marked square (15meters x 15meters).
2. Jogging with change of direction.
3. Skipping, using correct technique.
4. Jogging with side shuffles, left and right.
5. Jogging followed by high knees.
6. Jogging followed by heel flicks.
7. Jogging followed by dynamic calf stretch.
8. Jogging and skipping for height.
9. Hip mobilisation into forward lunge
10. Jogging with change of direction (increase pace)
11. Hip mobilisation into reverse lunge
12. Jogging with 3 x sprints in different directions.

Appendix E – Interview Questions

Name:.....

Date:.....

Team/School:.....

Coach/Trainer

Player

1. How did you find using the injury prevention warm-up programme throughout the season (training / match days) ?

2. In your opinion, was there too much/too little/right amount of content within the programme ?

3. **(coach)** Did the players need much correction of technique/form and was there improvement throughout the season ?

3. **(player)** Did you find the warm-up programme technically difficult (hard to do, easier as the year went on) ?

4. What is your opinion towards a structured warm-up programme like this (time/benefit) ?

5. Do you feel the programme had an impact on injuries during the season ?

6. Do you feel the programme had an impact on overall performance ?

7. In your opinion, what are the barriers, to the use of a structure warm-up programme like this ? (time, equipment, balls, cones, technical difficulty, coach memory, experience)

8. **(coach)** Would you recommend and use such programmes in the future?

8. **(player)** Would you be happy to participate in a warm-up programme like this in the future?

9. In your opinion, how would it be possible to increase the overall usage of an injury prevention warm-up programme like this one ?

Appendix F – Mobile Phone Application ‘Smartabase’

Screen shots of layout.

Stage 1 – Login details



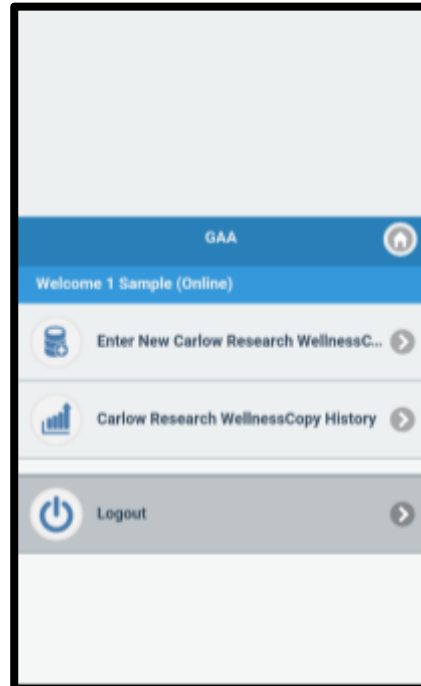
Smartabase Mobile

Username
sample.1

Password

Version 4.668 on 17-August-2015

Logis Online



GAA

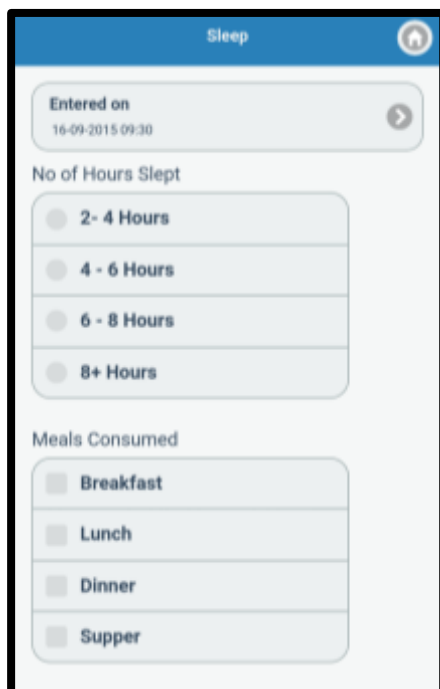
Welcome 1 Sample (Online)

Enter New Carlow Research WellnessC... >

Carlow Research WellnessCopy History >

Logout >

Stage 2 – Wellness Details



Sleep

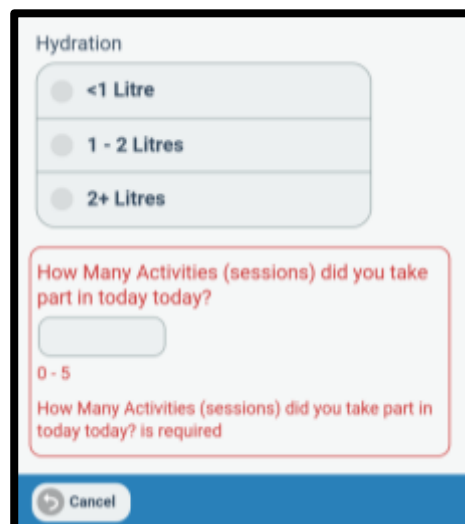
Entered on
16-09-2015 09:30 >

No of Hours Slept

- 2- 4 Hours
- 4 - 6 Hours
- 6 - 8 Hours
- 8+ Hours

Meals Consumed

- Breakfast
- Lunch
- Dinner
- Supper



Hydration

- <1 Litre
- 1 - 2 Litres
- 2+ Litres

How Many Activities (sessions) did you take part in today today?
0 - 5

How Many Activities (sessions) did you take part in today today? is required

Cancel


How Many Activities (sessions) did you take part in today today?

0 - 5

Why?

- Injured
- No Training
- Sick

Stage 3 – Activity Details

Training Details 1 

Daily Activity 1

- Match
- Training
- Gym
- None

What Sport? 1

- Hurling
- Gaelic Football
- Soccer
- Rugby
- Other

Activity For 1

- Club
- School
- County
- Other

Duration (mins) 1

- 0
- 30
- 40
- 50
- 60
- 70
- 80
- 90
- 100
- 110
- 120+

Did you complete the prescribed warm-up at the beginning of the session? 1

Yes

No

Cancel Previous Next

Stage 4 – Injury Details

Injury

Injury?

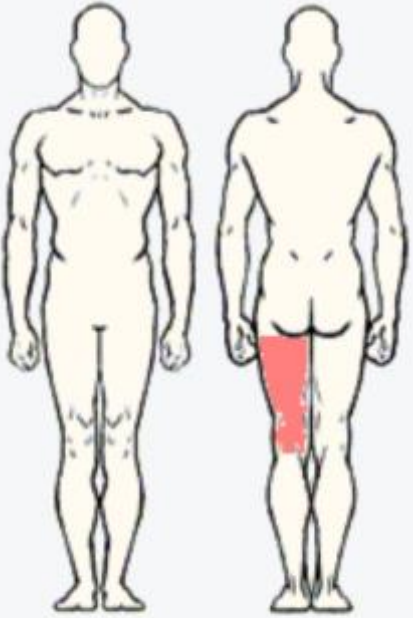
Yes

No

Did you get injured today?

Cancel Previous Next

Body Area



Selected:

Left Posterior Thigh

Remove

Recurring Injury?

Yes

No