INJURY INCIDENCE AND PREVALENCE IN NEW ZEALAND HIGH PERFORMANCE SPORTS

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Abstract

Introduction. Injury surveillance data is required to determine injury incidence and prevalence within different sporting codes. This allows injury prevention strategies to be targeted to the specific sports. High Performance Sport New Zealand (HPSNZ) has developed an injury surveillance system, part of which includes an online app, to monitor injuries within sports but its effectiveness has not yet been determined.

Purpose. To determine the injury incidence and prevalence in HPSNZ sports

Methods. One hundred and fifteen New Zealand carded athletes across the five sporting disciplines of men's hockey, women's hockey, women's football, kayaking and sailing completed a longitudinal prospective cohort study over twelve months. The sample was made up of 45 males (mean age 24.22 SD. 3.97) and 71 females (mean age 22.96 SD. 4.15) with data collected weekly using the HPSNZ "Programme for Injury and Illness Surveillance" (PILLS) self-reported injury surveillance app.

Results. The overall compliance rate was 60.63%. Injury incidence across the entire sample was 10.67/ 1000 athlete exposures (AE). The injury incidence for the five sports was as follows: men's hockey 14.15/1000 AE; women's hockey 13.38/1000 AE; women's football 8.18/1000 AE, kayaking 4.35/1000 AE and sailing 5.59/1000 AE.

Injury prevalence for the five sports was; 2.72 for men's hockey, 4.26 for women's hockey, 2.48 for women's football, 1.07 for kayaking and 1.33 for sailing.

Seventy-five percent of the entire sample experienced at least one time loss injury during the study duration.

Conclusion. Training injury incidence and prevalence was reported for five HPSNZ sports. The team sports had higher injury incidence and prevalence rates than both kayaking and sailing. The PILLS app allowed for training exposure estimates to be made however it requires further development, or needs to be used in conjunction with other monitoring systems, in order to capture all relevant injury data and competition exposure. It is suggested that exposure measures need to be captured using alternative methods rather than through the injury surveillance tool.

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CERTIFICATE OF AUTHORSHIP

"I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for publication for the qualification of any other degree or diploma of a university or other institution of higher learning, except where due acknowledgement is made in the acknowledgements"

Student: Jennifer Sayer

Signature: 

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requires further development, or needs to be used in conjunction with other monitoring systems, in order to capture all relevant injury data and competition exposure. It is suggested that exposure measures need to be captured using alternative methods rather than through the injury surveillance tool.

Chapter One – Introduction

1.1 Statement of the problem

High Performance Sport New Zealand (HPSNZ) is a government funded sporting body in New Zealand that invests, supports and works in partnership with a number of National Sporting Organisations (NSOs). The aim of both HPSNZ and their NSOs is to see more elite New Zealand athletes competing and performing on the World stage, particularly at the Olympic and Paralympic games, in addition to World championships. Currently HPSNZ funds 35 different NSOs (HPSNZ, 2016). From these 35 NSOs, 11 are tiered with rowing, cycling, sailing and athletics being the priority level one tiered sports; equestrian, kayak, netball and rugby-7s being tier two priority sports and snow sports and women's hockey being tier three sports (HPSNZ, 2016). The remaining 24 NSOs are campaign funded, and include men's hockey and women's football. Funding decisions are reviewed annually and also at the beginning of each Olympic cycle. Investment decisions depend on a number of factors, including future athlete potential, the quality of the high performance programme being run by NSOs and on performance (HPSNZ, 2016). It is therefore paramount that the NSOs and HPSNZ contribute to optimal performance of their athletes to secure adequate funding to continue the development of both their athletes and their programmes. To help with this, HPSNZ have developed a performance health model consisting of the following five elements:

i) Injury and illness management

ii) Injury and illness prevention

iii) Athlete monitoring

iv) Performance optimisation

v) Planning and coordination (HPSNZ, 2016).

One of the biggest barriers to athlete performance is injury, which can result in time loss from sport and compromised performance (Nilstad, Andersen, Bahr, Holme & Steffen, 2014; Thacker, 2007). In a high performance environment like HPSNZ, this can then have repercussions on future investment decisions for the sport. Therefore, an important role of the NSOs' medical teams is to implement injury prevention programmes to try to mitigate the occurrence and effect of injuries. Nevertheless, without an initial understanding of the injury problem facing a sport, interventions may not be targeted appropriately and their efficacy cannot be evaluated (Van Mechelen, Hlobil & Kemper, 1992; Finch, 1997). Currently there is limited epidemiological data on elite athletes in New Zealand. It is therefore paramount that injury surveillance is also part of the NSOs' medical teams' role to ensure prevention strategies are appropriate and targeted specifically to the demands of each individual sport.

In 2014, an injury surveillance system was developed at HPSNZ called the Programme for Injury and Illness Surveillance (PILLS), part of which was an online app, known as the PILLS app. This consists of up to 31 questions assessing an athlete's ability to train in the last seven days due to injury or illness restrictions. The PILLS app was developed to facilitate injury and illness data collection across all NSOs to help develop an understanding of the injury and illness patterns affecting different sports. Finch (2006) highlighted the importance of using injury surveillance tools that are validated and reliable. This is a theme that other researchers have touched on, as the tool used determines the outcomes achieved in injury surveillance studies (Bahr & Krosshaug, 2005; Meeuwisee, 1994).

1.2 The purpose of this study

The purpose of this study is two-fold. Firstly, to provide injury incidence and prevalence data across a variety of NSOs within the HPSNZ framework. Secondly, to assess the effectiveness of the HPSNZ developed PILLS as an injury surveillance tool for collecting all pertinent data surrounding athlete injury.

1.3 The significance of the problem

Injury surveillance is the cornerstone to any injury prevention programme and provides baseline data for future comparison to determine the efficacy of any preventative interventions that have been implemented (Van Mechelen et al., 1992).

Currently HPSNZ has a number of NSOs with multiple personnel involved in their medical teams. While many of these NSOs undertake their own injury surveillance, the high methodological variability impedes inter-NSO comparison. The PILLS provides a solution allowing all NSOs to collect the same injury information, however no investigation has been undertaken to determine the efficacy of this tool. Additionally, there is very little injury incidence and prevalence data published regarding New Zealand elite Olympic sports, something that this study aims to add to. By establishing baseline data sets for various New Zealand NSOs, this will facilitate a greater understanding of the significance of the injury problem in specific sports. The extent of NSO injury problems has yet to be formally identified within a New Zealand context, meaning that existing injury prevention programmes may not have been tailored adequately to meet the demands of each specific sport. Greater knowledge of injury incidence and prevalence in each NSO may help to determine more efficient resource allocation and more effective injury prevention programmes.

2 LITERATURE REVIEW

This chapter is divided into five main sections, the first of which will outline the importance of injury prevention and the role that injury surveillance plays in this process. The challenges with injury surveillance will then be outlined in section two. The third section of this chapter expands on injury definitions and the HPSNZ injury surveillance programme will be introduced in the fourth section. The fifth section of this chapter is a review of the literature investigating injuries in men’s and women’s field hockey, sailing, flat water kayaking and women’s football. This includes injury frequency, incidence and prevalence. The chapter then finishes with a summary.

2.1 Injury Prevention

Worldwide, sport has transformed from amateur recreational activities to a multi-million dollar industry (Couvelaere & Richelieu, 2005). With this sporting evolution, athletes now compete for lucrative contracts, prize monies, endorsement and sponsorship deals in addition to sporting success on the global stage (Couvelaere & Richelieu, 2005; Frederick & Patil, 2010). Performance determines how successful athletes are and a recognised limitation to performance is musculoskeletal injury (Thacker, 2007). Therefore, in professional sport, injury prevention is imperative to reduce the time that athletes are unavailable to either train or compete. For professional athletes and their coaches, it is their livelihoods at stake. It is therefore a primary task of medical teams to prevent injury occurring (Meeuwisse, Tyreman, Hagel & Emery, 2007). This is particularly important as previous injury is often a predictor of future injury, reinforcing that,

“Prevention is better than cure” (Gabbe, Bennell, Finch, Wajswelner & Orchard, 2005).

Van Mechelen et al. (1992) proposed a sequential prevention model comprising of four steps (see Figure 1). The steps are as follows;

Step 1: Identify and define the sports injury problem

Step 2: Establish the aetiology and mechanism of injuries

Step 3: Introduce preventative measures

Step 4: Repeating step one to determine the effectiveness of the measures

(Van Mechelen et al., 1992).

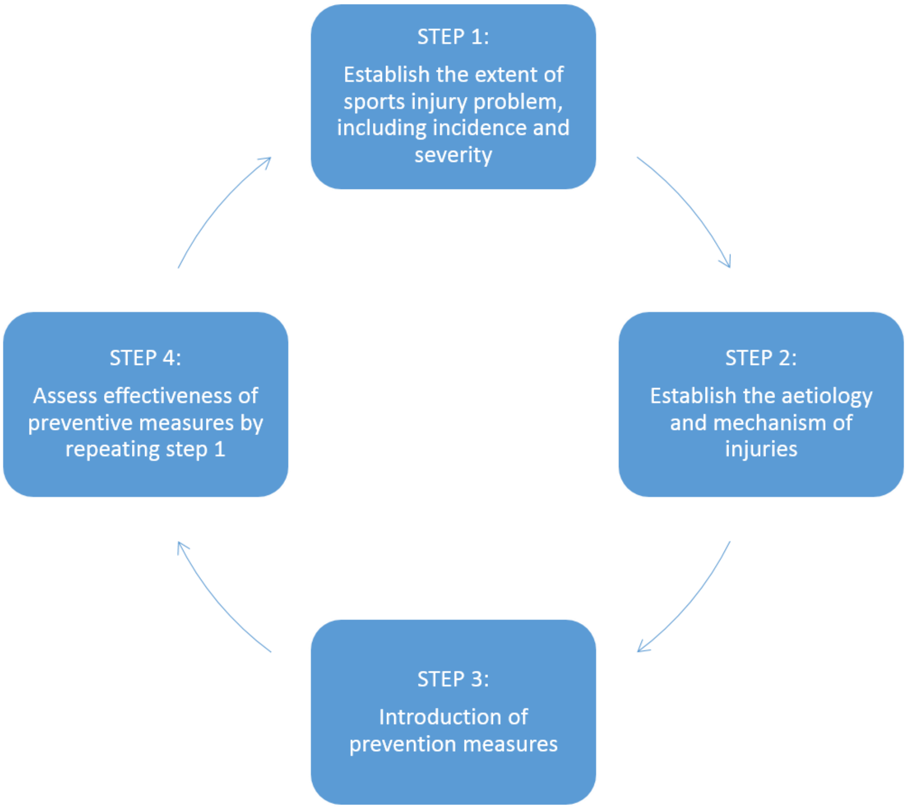

Figure 2.1 Sequential injury prevention model adapted from van Mechelen et al., 1992.

Van Mechelen et al. (1992) identified that the precursor to the development of an injury prevention programme for any sport, is a knowledge of the injury incidence and prevalence within that given population. This is incorporated in the first step of their model. These baseline measures then facilitate an understanding of the magnitude of the problem that injuries pose in a particular sport (Meeuwisse & Love, 1997). This knowledge can then be used to guide resource allocation and injury prevention programmes for that sport (Finch, Valuri & Ozanne-Smith, 1999). Subsequently, as per step four of Van Mechelen's model (1992), this injury data can then be used as a baseline outcome measure to assess the effectiveness of an applied intervention. Without these injury measures, the efficacy of interventions designed to reduce injuries remain unquantified.

Although often cited in injury surveillance and prevention papers, Van Mechelen et al.'s (1992) model does not capture all injuries. The authors themselves acknowledge that their model overlooks overuse injuries and there is no differentiating between re-injuries or exacerbations of an existing injury.

As a baseline model, Van Mechelen et al (1992) highlighted injury surveillance as the cornerstone of injury prevention programmes. They identified the importance of having standardised definitions of sports injury to facilitate inter-study comparisons and to allow meaningful data to be collected. The importance of calculating injury incidence rates rather than injury frequency was also identified by this group (Van Mechelen et al., 1992). This allows the number of injuries that are recorded to be expressed in relation to athletes' exposure in a particular sport therefore identifying how many injuries occur per time unit that the athletes are at risk. This time measurement is often expressed as 1000 hours of sport (Junge & Dvorak, 2000). By collecting injury data as injury incidence, rather than frequency, a more accurate analysis of injury risk in sport can occur.

Intrinsic and extrinsic risk factors fall under step II of Van Mechelen et al.'s (1992) model. Age, gender and previous injury are three common examples of intrinsic risk factors.

Examples of extrinsic ones include playing surface, environmental conditions and footwear. It is the sum of these risk factors, interacting with an inciting event that results in an athlete sustaining an injury (Meeuwisse, 2004; Bahr & Krosshaug, 2005). Indeed, Meeuwisse (2004) described the inciting event as the "link in the chain" when coupled with an individual's intrinsic and extrinsic risk factors. Bahr and Krosshaug (2005) developed this further by insisting that the inciting event description also includes details regarding the playing situation, player and/ or opponent behaviour, an overview of whole body biomechanics and a detailed localised biomechanical description of the joint/ tissue involved. They argue that through greater detail being recorded regarding the inciting event, injury prevention can be more effective (Bahr & Krosshaug, 2005). They also note that, in the case of overuse injuries, the inciting event can be quite distant from the time that symptoms presented, as in the case of a stress fracture (Bahr & Krosshaug, 2005). Through this comprehensive injury causation model proposed by Bahr and Krosshaug (2005), the multifactorial nature of injuries can be better identified resulting in more effective injury prevention measures. By identifying intrinsic and extrinsic risk factors and detailing inciting events in depth, factors that can be modified are identified and can be transposed into injury prevention programmes.

A limitation of all three of these injury prevention models is their linear nature, outlining a sequential injury process consisting of finite and separate stages. Unfortunately, sports injuries do not always follow this pattern. As Meeuwisse, Tyreman, Hagel and Emery (2007) note, the occurrence of a sporting injury does not necessarily result in a termination of sporting activity. Many athletes will continue to compete despite the presence of an injury, if injury severity allows. The motivation may stem from selection concerns if they have an injury break, an important competition or because they want to complete their season (Hammond, Lilley, Pope & Ribbans, 2011; Meeuwisse et al., 2007). Another relevant contributing factor to ongoing participation may be ease of access to medical personnel. For example, due to New Zealand's geographical isolation, many HPSNZ athletes have prolonged periods of training and competing overseas and they are not always fortunate enough to travel with their own medical team, which may result in a delay in accessing injury interventions.

Gissane, White, Kerr and Jennings (2001) present an alternative model for injury investigation which aims to expand on these linear models that they felt were too simplistic and did not take into account fluctuations in athletes' intrinsic and extrinsic risk factors. Gissane et al. (2001) view risk factors as fluid entities that vary due to factors such as an individual's sport exposure and their injury state. In the uninjured athlete, their model allows for primary prevention aiming to prevent injuries from occurring. These strategies may include prophylactic taping of ankles, or biomechanical counselling to ensure appropriate landing strategies, therefore reducing injury occurrence (Gissane et al., 2001). This model promotes the multifactorial nature of sports injuries furthering the work of Meeuwisse (1994). The cyclical nature of Gissane et al.'s model (2001) highlights that a sports injury is not the end point in an injury prevention model. Rehabilitation and return to sport are a continuation of the model, both of which contribute to injury prevalence, with the goal of returning the athlete to the start of the model again. Once an athlete re-enters this model, they again will be exposed to intrinsic and extrinsic risk factors, some of which may have changed due to their previous injury. For example, a history of hamstring injury is one of the greatest predictors of a future hamstring injury, so such an injury therefore alters an athlete's intrinsic risk factors for future similar injury (Gabbe et al., 2005).

Meeuwisse et al. (2007) developed this further with the dynamic recursive model, which takes into account the consequences of repeated sports participation with and without injury. They note that repeated exposure to a sport can result in strengthening of an athlete in those activities which then reduces their intrinsic risk of injury in that activity. Conversely, they also note that repeated activity could also result in microtrauma making an individual more susceptible to injury when participating in that sport. They refer to these changes as adaptations and mal-adaptations (Meeuwisse et al., 2007).

Both Gissane et al.'s (2001) and Meeuwisse et al.'s (2007) models identify that intrinsic and extrinsic risk factors are not stable components in an athlete's career resulting in variability in an individual's susceptibility to injury at different times. Injury prevention programmes therefore need to be adaptable to these variations in order to be effective. The evolution from linear injury prevention models, to those more cyclical in nature promotes greater adaptability. Both of these models allude to the multifactorial nature of injuries and how previous injury may result in altered risk factors for athletes. Despite the existence of these models, and the knowledge that injury surveillance can direct appropriate injury prevention interventions, not all sports comply with either step (Finch, 2006). To help to enhance compliance, Finch 2006 developed the Translating Research into Injury Prevention Practice (TRIPP) model outlined in Figure 2.2.

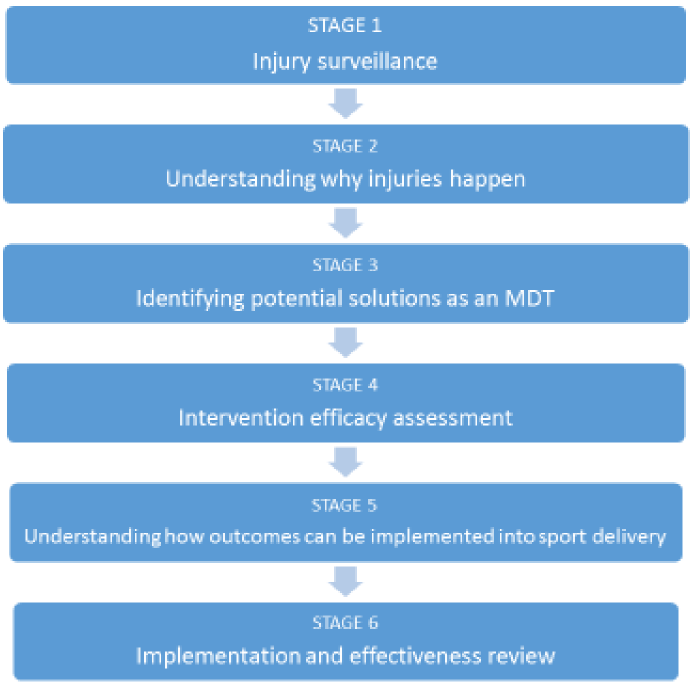

Figure 2.2 TRIPP model adapted from Finch (2006)

The TRIPP model incorporates the van Mechelen model within its first step, and the subsequent models of Meeuwisse et al. (1994; 2004), Gissane et al. (2001) and Bahr and Krosshaug (2005) feature in stage two which emphasises the importance of understanding why sports injuries happen. The TRIPP model has four other stages which emphasise the importance of evaluating the implementation of effective injury prevention interventions within a sporting context and ensuring an effective delivery and uptake by sports (Finch, 2006). This is an important facet of injury prevention which has previously been overlooked. While a highly effective injury prevention programme can be established, if sports do not use it, it will be ineffective.

Summary

Injury prevention is an important requirement in elite sport and numerous theoretical models for injury prevention strategies have been proposed. Injuries are multifactorial in nature and occur usually because of a combination of intrinsic and extrinsic risk factors and inciting events. For any injury prevention programme to be effective, a baseline knowledge of the injury problem is required which can then be used as an objective marker to evaluate the efficacy of any interventions. It is important that an injury baseline identifies all types of injuries to provide a true and accurate picture of the injury problem within a particular sporting population. This baseline data is acquired through injury surveillance which is the process of collecting and analysing injury data, a process frequently fraught with challenges. These challenges will be outlined in the next section of this chapter.

2.2 Injury Surveillance and its challenges

Injury surveillance is the collection of injury data using structured and systematic processes (Finch & Mitchell, 2002). This data is then used in enabling injury issues and trends to be identified, incidence and prevalence to be determined and any subsequent interventions to be evaluated (Van Mechelen et al., 1992; Finch 1997). Injury surveillance is the foundation of any injury prevention programme however it is an undertaking that can be challenging. This section will review different study designs, compliance issues and sources of bias all of which contribute to the challenges encountered in injury surveillance.

2.2.1 Case studies vs cohort studies. The study design is essential for injury surveillance because it immediately determines how the data is interpreted and how the results are applied (Meeuwisse & Love, 1997). The two main designs for injury surveillance studies are case series and cohort design. While case series are good for rare and serious injuries, which possibly limit an athlete's career, they do not take into account exposure measures and therefore no inferences can be made about injury incidence or prevalence from this design (Meeuwisse & Love, 1997). Cohort studies offer the opportunity to record and accurately measure an enrolled population's exposure to injury risk over a predetermined period of time (Hagglund, Walden, Bahr & Ekstrand, 2005; Meeuwisse & Love, 1997). This design allows for greater data analysis through improved reporting, including exposure measures which allow injury incidence to be reported and injury risk to be estimated rather than just reporting injury frequency (Hagglund et al., 2005; Meeuwisse & Love, 1997; Van Mechelen et al., 1992). The drawback of cohort studies is that they require greater investigator effort to collect and analyse the larger datasets obtained, while a case series is simpler due to less data to manage (Meeuwisse & Love, 1997).

2.2.2 Retrospective vs Prospective studies. Most cohort studies are prospective in nature with the cohort being enrolled at the beginning of the study and followed through until the end of the study duration, which may be the end of a year or the end of the playing season, depending on the study's aims (Hagglund et al., 2005; Meeuwisse & Love, 1997). Any injuries sustained within the study duration are recorded in "real time" which then negates the recall bias that occurs with retrospective data (Hagglund et al., 2005).

In their twelve month study, Junge and Dvorak recorded all injuries in a sample of Czech football players weekly (2000). A physician assessed and questioned the players on a weekly basis for the whole year, then at the end of twelve months, each player was asked to complete a retrospective questionnaire for the study period (Junge & Dvorak, 2000). They therefore had prospective weekly data and retrospective questionnaires for 248 players. A significant difference was found between the weekly and the retrospective data with 558 injuries being reported in the weekly data set compared with only 164 in the retrospective data (Junge & Dvorak, 2000). Using retrospective injury reporting measures resulted in nearly two thirds of all injuries going unreported and, as a result, also led to exposure being overestimated. Furthermore minor to moderate injuries were the ones most impacted by poor recall, particularly if they had happened a while ago (Junge & Dvorak, 2000). Nearly eighteen percent of the sample also forgot to report their severe injuries including fractures and therefore it cannot be concluded that only mild to moderate injuries would be overlooked in retrospective studies (Junge & Dvorak, 2000). This highlights the limitations and validity of data acquired retrospectively as recall bias pervades the results and would likely skew injury incidence estimations. A prospectively designed study is not only less susceptible to recall bias, it is more structured and monitored resulting in more complete data sets (Meeuwisse et al., 2007), making it the more preferred study design for injury surveillance investigation.

2.2.3 Athlete completed vs medical personnel. Injury surveillance monitoring is usually completed by either the athlete themselves or by medical personnel involved within that sport. Both of these strategies can be susceptible to bias. Athletes may be reluctant to disclose their injuries due to fears surrounding selection, contracts and loss of earnings for not competing (Hammond et al., 2011) Additionally, it is often viewed as commonplace for athletes to compete/ train while experiencing pain, therefore they may under report injuries because they deem them as a normal part of being an elite sportsperson (Hammond, Lilley, Pope, Ribbans & Walker, 2013; Meeuwisse et al., 2007). Although athletes will have the superior knowledge of their symptoms with an injury, they may be unable to provide a diagnosis. For some, this could be because they are training and playing overseas and there is a communication barrier between them and their medical personnel. For athletes who experience chronic discomfort, they may defer seeking care for it until after competition or out of their playing season – therefore their diagnosis may be self-generated and factually incorrect compared to medical diagnoses. Conversely the opposite could also be true, and athletes may over-report issues. This could occur in pre-season games, or around non-essential trainings where an athlete may be experiencing some muscle tightness and by reporting it as an injury, it may provide an opportunity for them to "rest" from this non-essential activity enabling them to avoid worsening it which could have resulted in an injury (Hammond et al., 2011).

It can be assumed that due to their professional expertise, medical personnel provide more objective and factually accurate information than athletes in injury surveillance, however, their response can still be susceptible to bias. This can occur in terms of their clinical practice and diagnostic abilities, or it could also be present if injury definitions are unclear. For example, if a clinician is clearing an athlete as fit to compete, even if they are having ongoing treatment, there may be reluctance to document them as injured as this then undermines the clinician's decision to return them to play (Hamilton, Meeuwisse, Emery & Shrier, 2011).

2.2.4 Compliance. A major challenge in injury surveillance studies is compliance as data collection is reliant on either athletes or nominated staff completing appropriate injury forms in a timely manner. In their study into injury surveillance in community sport, Ekegren, Donaldson, Gabbe and Finch (2014) identified both facilitators and barriers to the adoption of injury surveillance tools which fell under the three categories of personal, socio-contextual and system factors.

Personal barriers to implementation revolved around the perception that injury surveillance was unimportant while conversely, a belief in injury surveillance and a belief that it was the role of a sports trainer to implement it led to greater compliance (Ekegren et al., 2014). Compliance was reduced by the staff not understanding the importance of injury surveillance, the underreporting of injuries by the athletes and the absence of a leader implementing the injury surveillance (Ekegren et al., 2014). In athlete completed injury surveillance, a reluctance to disclose injuries may lead to false negative results being obtained, or may mean that the athlete does not complete and return data, both of which demonstrate non-compliance. The former would result in altered injury frequencies and incidence whereas the latter produces incomplete data sets (Ekegren et al., 2014).

Conversely, Ekegren et al (2014) found an investigator association with a parallel run injury prevention programme improved compliance rates from those clubs. This suggests that additional engagement with the clubs increased compliance. Hammond, Lilley, Pope and Ribbans (2014) had 100% compliance in their season long prospective cohort study investigating injuries in three football teams. Injury surveillance was undertaken by the three club physiotherapists and the lead researcher met with them either weekly or fortnightly to collect the data. The high level of compliance achieved in this study was attributed to this regular interaction between investigators and team staff (Hammond et al., 2014).

Having an easy injury surveillance tool to use has been shown to increase compliance whereas technical issues, and the introduction of a new system may reduce compliance (Ekegren et al., 2014). The adoption of a new system has been mentioned previously before by Finch et al. (1999) as a barrier to compliance, however they overcame this by offering training for those who were going to be completing the surveillance. Additionally, they noted that compliance was fostered through the timely presenting of results at the end of each day so that the value in the data collection was immediately evident to sporting bodies and organisations involved (Finch et al., 1999).

Ekegren et al.'s study (2014) was based in a community sport setting where injury surveillance is a non-essential operation. Within elite sport, injury surveillance is an important role of medical personnel in order to be able to allocate resources appropriately, a contributing factor as to why the majority of injury surveillance systems identified in a recent literature review completed this year exist within an elite/ professional sports setting (Ekegren, Gabbe & Finch, 2015). HPSNZ is a relatively new organisation working with multiple NSOs. While many of these NSOs have undertaken limited injury surveillance, few are systematic or comparable to other sports due to methodological differences.

2.2.5 Sources of bias. As mentioned previously in this section, in both athlete or staff completed injury surveillance, under and over-reporting can contribute to bias (Hammond, Lilley, Pope & Ribbans, 2011; Hammond, Lilley, Pope, Ribbans & Walker, 2013). This can result in inaccurate injury incidence, prevalence and risk estimations. Retrospective studies are influenced by recall bias so the way to negate this is to use a prospective study design (Hagglund et al., 2005; Meeuwisse & Love, 2007).

Studies which use "medical attention" definition for injuries may be exposed to bias in sports where medical personnel are easily accessible. This may result in a higher injury incidence being recorded because of the ease of access to personnel (Clarsen & Bahr, 2014). If injury surveillance is being utilised to determine future research allocation, this is a factor that requires careful consideration.

Clinicians may have different interpretations of diagnoses and severity classifications. This can impact on return to sport decisions and alter injury surveillance data. For example, from a pathological standpoint, an injury will take much longer to "heal fully" compared with using a "Return-to-sport" definition for recovery (Hamilton et al., 2011). Therefore, determining an injury as fully healed once an individual stops seeking medical treatment may be the more reliable way to determine injury severity, rather than the point at which they return to sport. This "cessation of treatment" recovery definition has greater "face validity" than the "return to sport" definition because if an athlete is still receiving care for an ongoing problem, it suggests that it has not fully resolved. A drawback of this definition is that it requires more in-depth data collection than using the finite cut-off point of when an athlete returns to sport (Hamilton et al., 2011).

To overcome and avoid some of these discrepancies occurring in the data, standardised definitions which are clear and unambiguous should be utilised for injury surveillance. The next section of this chapter will outline the various definitions that currently exist.

2.3 Injury Definitions

Injury incidence and prevalence are calculated through injury surveillance. Comparisons between injury surveillance studies have previously been limited due to varying parameters, definitions and methodologies used (Finch, 1997; Van Mechelen et al., 1992). Initially, the term injury needs to be defined and this has been a variable that differs between many studies leading to difficulties with inter study comparisons (Gissane et al., 1997). Lack of clear injury definitions may result in under or over reporting of injuries in injury surveillance studies resulting in inaccurate injury data.

Consensus statements have been developed for use in a variety of sporting codes ranging from team sports such as football, rugby and cricket (Fuller et al., 2006; 2007; Junge & Dvorak, 2013; Ranson, Hurley, Rugless, Mansingh, Cole, 2013), individual sports such as tennis (Pluim et al., 2009) and at multi-disciplinary events such as World athletic championships (Alonso et al., 2009; Alonso et al., 2010). These consensus statements are aimed to reduce the heterogeneity of epidemiological studies and facilitate cross comparison between various sports through the provision of injury definitions, study methodology and appropriate analyses (Fuller et al., 2006).

In their consensus statement for recording football injuries, Fuller et al. (2006) defined an injury as

"Any physical complaint sustained by a player that results from a football match or football training, irrespective of the need for medical attention or time-loss from football activities."

The following year, this was then expanded in the rugby union consensus statement to include

"Any physical complaint, which was caused by a transfer of energy that exceeded the body's ability to maintain its structural and/or functional integrity, that was sustained by a player during a rugby match or rugby training." (Fuller et al., 2007).

Pluim et al. (2009) developed this further to incorporate illness (including psychological complaints) in addition to injury under the umbrella term of "medical conditions" when related to injury surveillance in tennis.

In all three consensus statements, a commonality is that the injury needs to have been sustained while training or participating in that sport to be recorded in injury surveillance. In the HPSNZ environment, many athletes use the gym and alternative training facilities to develop attributes desirable for optimal performance. If these sessions occur under the guidance of the sport's management team, they are considered to be a training exposure. If the athlete is undertaking an activity on a recreational basis and an injury occurs, this would not be recorded in the injury surveillance (Fuller et al., 2006). Additional rehabilitation work undertaken by athletes in the gym is also not considered as training according to Fuller et al. (2006). In the HPSNZ environment, this rehabilitation work is often incorporated into individual's gym sessions.

Injuries can be classified into three broad categories: time-loss injuries, medical attention injuries and all complaints (Clarsen & Bahr, 2014; Fuller et al., 2006; 2007; Junge & Dvorak, 2013; Pluim et al., 2009). Out of these three, time loss injuries are the narrowest category and all complaints are the broadest (Clarsen & Bahr, 2014). According to the consensus statements, time loss injuries are when an individual is unable to fully participate one hundred percent in training and/ or competition (Fuller et al., 2006, 2007; Pluim et al., 2009). One of the benefits with this injury definition is that recording these injuries is easier. As Clarsen and Bahr (2014) point out, no medical expertise is required to identify a time-loss injury, therefore it is a simple way to record injuries, particularly in athletes who are away overseas with no medical support. However, time-loss injuries can overlook some injuries in injury surveillance. For example, a footballer may be able to complete a full training with the omission of a slide tackling drill. While they may have completed 95% of the session, because of the restriction in one area, it would be recorded as a time loss session because they could not complete everything. In individual sports, sessions may be modified to occur on different days to work around an injury. For example, a planned heavy training week may be postponed due to a rib stress reaction for a K1 kayaker. They may still be able to complete full training sessions, however their plan may have been modified to reduce the intensity while their injury settles. A large number of time loss injuries may be unreported due to the athletes taking medication to mask their injury or delaying treatment/ activity withdrawal until after pinnacle events or hard training blocks (Clarsen & Bahr, 2014; Meeuwisse et al., 2007).

The time loss injuries category can be further narrowed if it is restricted to missed matches as is the case in cricket injury surveillance (Ranson et al., 2013). This restriction on injury classification can result in injuries being missed. As previously mentioned, Hammond et al. (2014) found in their football study that during one season, there were 102 instances when athletes played while injured. This occurred for 45 injuries, which would mean that if using either a “time-loss” or “missed match” injury definition, these injuries would not have been recorded. In their qualitative study, Hammond et al. (2013) noted that athletes perceived that it was a normal part of sport to play through injuries, suggesting that it is not an uncommon practice. Orchard and Hoskins (2007) acknowledge the fact that athletes play with injuries and argue therefore that a “missed match” definition is the most reliable injury categorisation in team sports. They highlight that trainings may be modified to accommodate chronic long-term injuries, for example the first training each week post game may be missed to enable a player to recover adequately enough to be able to play the next game. If using a time-loss definition, this injury should be recorded as an index injury initially with an exacerbation each week due to non-participation in the first training of the week. Orchard and Hoskins (2007) identify that it is unlikely that investigators will record it as such, therefore bringing into question the reliability of “time-loss” definitions.

Limitations of the missed match definition include its inability to take into account injuries sustained in the last game of a season; its lack of applicability for sports such as kayak or swimming which do not have regular weekly competition meets and it also can be misleading when fixtures occur with greater frequency than once a week (Orchard & Hoskins, 2007).

"Medical attention" injuries as the name suggests, are complaints for which athletes have sought medical expertise (Fuller et al., 2006; 2007). This injury classification is also susceptible to bias, for example when based domestically in New Zealand, HPSNZ athletes have easy access to their medical teams and can schedule appointments whenever they need. This may result in minor complaints being recorded as injuries merely because of the convenience of getting a medical opinion in New Zealand. When based overseas, many of these athletes have periods with no medical support, therefore are less likely to report any "medical-attention" injuries during that time. This may not be because they are not injured but because there are language barriers, restricted access and resources meaning that the athlete may choose to self-manage until they are back in their domestic environment or until there is easy access to medical personnel. The lack of medical support may increase the threshold at which an athlete considers themselves to be injured compared to when they are in the domestic training environment.

It is common for athletes at the elite level to continue to train and compete with pain and functional deficits from injuries, without seeking medical assistance meaning that these injuries would not be identified by time-loss, missed-match or medical attention injury definitions (Bahr, 2009; Clarsen, Myklebust & Bahr, 2013; Meeuwisse et al., 2007).

The broadest category is all complaints which details all issues and discomfort experienced by athletes. Systematic bias can occur with this definition due to variable thresholds in athletes concerning what is a reportable event and what is not (Clarsen & Bahr, 2014; Hammond et al., 2014). Psychological considerations may also play a part, as some individuals dislike focusing on any impairment or restriction they may have, so will under-report while other athletes may over report (Hammond et al., 2011). It is not uncommon for athletes to experience discomfort following heavy training loads. Therefore, injury definitions need consideration and outlining to those completing injury surveillance questionnaires. This education should then prevent the over-reporting of minor complaints which are not defined as injuries which could skew injury data collected for that sport. Another consideration when using an "all-complaints" injury classification is that it is much more labour intensive for the researchers compared with merely documenting whether an athlete was available for training or playing (Hodgson, Gissane, Gabbett & King, 2007). Nevertheless, if a "missed-match/ time-loss" definition is employed then the number of physiotherapy or medical contacts for a "transient" injury through which an athlete can continue to train and play become overlooked and the true picture of injury incidence in a particular sport may be under-reported (Hodgson et al., 2007). This is why only documenting injury frequency in a sporting code is insufficient as it only elucidates part of the problem (Van Mechelen, 1997).

One possible solution may be to collect information pertaining to the number of trainings or competition sessions that have been modified by an athlete during the week. This will capture a clearer picture than just time-loss injuries would, but also will take into account athletes who are overseas who have problems but who may not have easy access to medical facilities.

In addition to defining injuries, the injury type needs documenting. The first injury recorded for an individual in an injury surveillance study is referred to as an index injury (Hamilton, Meeuwisse, Emery & Shrier, 2011). Any other injury then recorded for that individual during the course of the study is then referred to as a subsequent injury (Finch & Cook, 2014; Hamilton et al., 2011). The latter subgroup of injuries is often under reported in epidemiology studies due to variable injury definitions.

Hamilton et al. (2011) subdivided subsequent injuries into new, recurrent and local. New injuries were to a different body site, recurrent injuries were a repeat of the index injury and local injuries occurred to the same body region as the index injury but were different - for example a lateral ligament sprain to the ankle, following a previous deltoid ligament sprain (Hamilton et al., 2011). Fuller, Bahr, Dick and Meeuwisse (2007) further divided recurrent injuries into exacerbations and reinjuries. Exacerbations were defined as the worsening of a non-recovered index injury whereas reinjuries are the recurrence of the same injury following complete healing of the index injury (Fuller et al., 2007).

The above definitions of subsequent injuries necessitate a definition of full healing. Full healing is often based on either the date the athlete returned to play or the date of the last treatment for a specific injury (Hamilton et al., 2011). However, Hammond et al. (2013) describe three criteria for recovery which are; availability for match selection, availability for training and medical opinion. As previously alluded to, it is often the case that athletes will return to competition while still injured (Bahr, 2009; Hammond et al., 2011; 2014) therefore taking the date an athlete returned to either training or play, can result in a greater number of exacerbations being recorded as full healing will not have occurred and this may misrepresent the magnitude of injuries in a sports. If an athlete is still seeking therapeutic intervention for an injury, despite having returned to competition, this suggests that full healing has not yet occurred. It could therefore be argued that the final treatment definition of fully healed has greater face validity than return to play (Hamilton et al., 2011).

In 2014, Finch and Cook presented a subsequent injury categorisation (SIC) model, comprising of ten categories, to facilitate classification of new/index and subsequent injuries. It covers exacerbations, reinjuries, acute injuries, ongoing injuries, injuries to the same body site and injuries to different body sites (Finch & Cook, 2014).

Finch and Cook (2014) followed 1564 community Australian football players with 1082 injuries prospectively over the playing season from 2007 and 2008. Analysis demonstrated that 469 of the recorded injuries were subsequent injuries. When coded using the SIC model, 15.6% of these 469 subsequent injuries were directly linked, through anatomical site and pathology, to an original index injury (Finch & Cook, 2014). This model may help to provide a greater understanding of a sport's injury problem, and the true impact that index injuries have on an athlete. This should then enhance the accuracy of the knowledge of the injury problems facing a sport and allow for effective evaluation of injury prevention programmes (Finch & Cook, 2014). The drawback with the SIC model is that it requires in-depth reporting of injuries and so is a more time consuming process. However, the data that is then available for analysis provides a more detailed and accurate picture of the reality of the injury problem in that sport. This should then help to reduce the over- reporting of new injuries and the under reporting of recurrent injuries.

While "time-loss" and "medical attention" injuries capture injuries which prevent individuals from being able to play or train fully, or requiring medical intervention, they often do not take into account overuse conditions, chronic problems or non-severe acute injuries through which athletes can continue to play and train without seeking medical help. These types of injuries are often overlooked and under reported in epidemiological studies, particularly those which use a time-loss injury definition. Clarsen, Myklebust and Bahr (2013) developed an overuse injury questionnaire, the Oslo Sports Trauma Research Centre (OSTRC), for use in sporting populations that could be applied to any body part. The focus of this questionnaire is on the consequences from an injury with each answer allocated a severity score out of 100. This score identifies the extent of the impact that the injury has on an athlete's participation. The greater the magnitude of the problem, the greater the severity score will be (Clarsen et al., 2013). They employed it over a three month period and emailed it out to athletes on a weekly basis. They also looked at the results if they sampled less frequently. This was found to result in fewer cases of overuse injuries being identified but this did not affect the average prevalence or severity scores (Clarsen et al., 2013). As well as capturing overuse injuries which are often missed in injury surveillance studies, another benefit of using the OSTRC is that it provides a severity score for reported problems helping to identify the impact the problem is having on the athlete (Clarsen et al., 2013).

Clarsen et al. (2013) undertook a thirteen week study across five sports to compare the information captured from standard injury surveillance methods compared with the information captured using the OSTRC. Standard injury surveillance methods using time-loss injuries identified 40 injuries, while the overuse injury questionnaire registered 419 injuries in the same group of athletes over the same time frame thus demonstrating how easily a "time loss" definition can under report in sports injury studies (Clarsen et al., 2013). This work was developed further in a 40 week study monitoring illness and injury in a sample of 142 athletes in the build up to the 2012 Olympic and Paralympic Games (Clarsen, Ronsen, Myklebust, Florenes & Bahr, 2014). Out of 617 health problems reported, 49% of these were overuse injuries compared to 13% acute injuries (Clarsen et al., 2014). This highlights the importance of capturing information about overuse injuries. Previously, injury surveillance studies have opted to use time loss as a measure of an injury's severity (Fuller et al., 2006). If no time is missed because of the injury, that is defined as a 0 day severity. Clarsen et al (2013) found that even with 0 day severity, some injuries still had detrimental effects on athletes' performance and participation which could last for numerous weeks – factors which would not have been identified using consensus statement definitions alone, but which are illuminated in the OSTRC.

For injury surveillance to be effective, it is paramount to have clear injury definitions to ensure consistent recording of athletes' complaints. Using standardised definitions found in the literature also encourages inter study comparisons. To establish incidence and prevalence, exposure time needs collecting. To capture all of this information, an appropriate tool needs to be used. The next section outlines the tool currently employed by HPSNZ.

2.4 HPSNZ Injury Surveillance Tool.

An internet search for sports injury surveillance tools brings up a number of systems in the United States of America. There is the National Electronic Injury Surveillance System – All Injury Program (NEISS-AIP) (Coronado et al., 2015), The National Collegiate Athletic Association Injury Surveillance System (NCAA – ISS) (Dick, Agel & Marshall, 2007) and the high school reporting information online (RIO) system (Yard, Collins & Comstock, 2009). The NEISS-AIP is concerned with injury presentations in emergency departments while the other two systems are completed by athletic trainers and document sports exposure and injury data. The NCAA-ISS has been collecting injury and exposure data since 1988 from a representative sample of American colleges (Dick et al., 2007). It became web-based in 2003-2004, has set definitions for injury and for athletic exposure and has standardised reporting paperwork which is provided, along with comprehensive instructions, to the relevant athletic trainers at the start of the academic year (Dick et al., 2007). RIO is a similar online data collection tool used for the National High School Sports-Related Injury Surveillance Study (Program for Injury Prevention, Education and Research, nd). It utilises the same definitions as the NCAA-ISS for both injury and exposure, however, its population is solely high school athletes (Yard et al., 2009). Both NCAA-ISS and RIO are completed by athletic trainers and capture injury details and mechanism (Dick et al., 2007; Program for Injury Prevention, Education and Research, nd.) In a high school setting, this can be a limitation if the funding does not exist to employ an athletic trainer, as then the data does not get collected.

In 2014, HPSNZ's medicine and rehabilitation team implemented a strategy for data collection known as the "Programme for Injury and Illness Surveillance (PILLS)." PILLS utilises a smart device application for self-reported data collection, in addition to a range of other sources of information, to collect health data on carded athletes. The PILLS app is a web based self-reporting injury and illness application for HPSNZ's carded athletes consisting of thirty one questions (see Appendix A). The primary purpose of the PILLS was to capture weekly data on all athletes, alerting their medical team to any issues. A secondary benefit was that regular completion would then result in an injury and illness profile being captured for individual athletes, and for the NSOs. This could then be used to target specific needs of individuals in their rehabilitation programmes, and to allow NSOs to understand injury and illness trends, and to allow appropriate allocations of resources as needed.

The PILLS app is a downloadable application run through smart phones and tablets. Each individual athlete is assigned a unique code when they download the application. Each week, the athlete is then required to open the application on their device and complete the questionnaire for the previous seven days. This completion has to occur while the device is connected to the internet. The results are then logged against the unique ID and are uploaded and stored in a password protected central database.

The PILLS app collects information on planned, missed and modified training sessions; whether an injury or illness has been present and their readiness to compete. It also records any contacts with medical personnel that have occurred in the last week. Because it is a self-reported questionnaire, the information received is only as accurate as the reporting from the athletes. However, it was a pragmatic starting place for HPSNZ to try to address the complex issue of injury surveillance. If an athlete has not missed or modified any sessions and does not have any injury or illness, the PILLS application applies step logic resulting in an abridged questionnaire. For those who have missed sessions because of injury or illness, further questions into the details are asked. Each week the physiotherapist assigned to each

NSO can observe who has completed the database, and follow up with individuals who have not. This then captures health information for HPSNZ sports.

The final section of this chapter will examine injury surveillance studies already published in field hockey, flat water kayaking, sailing and women's football.

2.5 Injury Incidence per Sport

2.5.1 Field Hockey. A literature search was carried out using Medline, Cinahl and Sports Discus databases via EBSCO as shown in Figure 2.2. The keywords were Injur* AND field AND hockey. The inclusion criteria were full original research academic journal articles, English language, published since 1990 and athletes of collegiate, professional, elite or international standard. This resulted in 19 studies being retrieved for review, the results of which are outlined in Table 2.1.

Four of the 19 studies looked at collegiate hockey players (Bowers, Baldwin & Sennett, 2008; Dick, Hootman, Agel, Vela, Marshall and Messina, 2007; Gardner, 2015; Hendrickson, Hill & Carpenter, 2008), six studies looked at elite hockey players (Freke & Dalgleish, 1994a; 1994b; Fuller, 1990; Naicker, McLean, Esterhuizen & Peters-Futre, 2007; Rishiraj, Taunton & Niven, 2009; Sharma, Seth & Koley, 2012), eight studies focused on international level field hockey players (Engebretsen et al., 2013; Hendrick, Farrelly & Jagger, 2008; Junge et al., 2004; 2009; Kelly & Hudson, 2010; Mukherjee, 2012, 2013; Thielen, Mueller-Eising, Bettink & Rolle, 2015) and one study had a mixed population ranging from high school students through to national level players (Murtaugh, 2001).

From these 19 studies, five had a mixed gender population (Engebretsen et al., 2013; Junge et al., 2004; 2009; Kelly & Hudson, 2010; Thielen, et al., 2015), 11 focused on female field hockey athletes (Bowers et al., 2008; Dick et al., 2007; Freke & Dalgleish, 1994a; 1994b; Fuller, 1990; Gardner, 2015; Hendrick et al., 2008; Hendrickson et al., 2008;

Murtaugh, 2001; Naicker et al., 2007; Rishiraj et al., 2009) and the remaining three investigated male field hockey players (Mukherjee, 2012, 2013; Sharma et al., 2012).

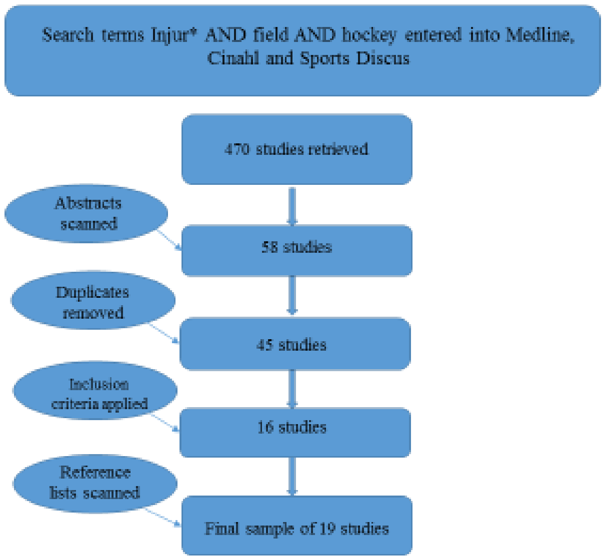

Figure 2.3 Flow diagram outlining literature search for injuries in hockey

Table 2.1

Overview of hockey studies

Study	Participants	Study Design	Injury Definition	Outcome measures	Results
Fuller, 1990	All female hockey players involved in tournament matches – sample size and age range not documented	Prospective observational cohort study	Presence of pain, discomfort or disability from participating in a hockey game that required physio attention	Match injury frequency	135 injuries from 100.5 hours of match play 1.34 injuries per hour of match play
Freke & Dalgleish, 1994a	40 female Queensland state hockey players with average age of 21.6 years	Retrospective historical injury study	Injury sustained during hockey resulting in hospitalisation/ medical attention or timeloss of over a week	Injury frequency	2.37 injuries/ player
Freke & Dalgleish, 1994b	62 female elite Queensland hockey players – age range not provided	Retrospective study using touring records from four Australian National Championships	Physiotherapy treatment required	Injury frequency	1.9 injuries/ player over four tournaments
Murtaugh, 2001	158 female field hockey players (aged 14-32)	Retrospective cross sectional descriptive study	Acute injuries	Injury rates Injury prevalence	74.7% reported an acute injury Overall rate of injury was 0.44 injuries/athlete year
Junge et al., 2004	Male and female hockey players at the 2004 Olympic Games age and sample size not stated	Prospective cohort study	Physical complaint resulting from match requiring medical attention, regardless of outcome	Injury frequency Injury incidence	44 injuries from 52 field hockey games 0.85 injuries/game (CI 0.6-1.1) 39 injuries/ 1000 player matches (CI 27-50) 18 time loss injuries – incidence 16/1000 player matches (CI 9-23) 4x greater injury rate in men’s hockey than women’s Men 55 injuries/ 1000 player matches (CI 37-72) Women 17 injuries/1000 player matches (CI5-29)

Continued

Study	Participants	Study Design	Injury Definition	Outcome measures	Results
Dick et al., 2007	Collegiate female hockey players, sample numbers and age range not stated	15 year study Prospective epidemiological study	Resulted from playing an organised game or training for hockey, required medical attention and resulted in time loss	Practice injury incidence Game injury incidence	Game injury incidence per 1000 AE 7.87 Practice injury incidence per 1000 AE 3.70
Naicker et al., 2007	47 elite provincial hockey players (age range 17-29)	Single, post season, athlete completed, retrospective questionnaire	Damage that resulted in pain +/- time loss of at least 5 days from hockey	Injury incidence	Overall injury rate 0.98/player/season Injury incidence 6.32/1000hrs of playing time
Bowers et al., 2008	Collegiate athletes in “stick handling sports” field hockey, lacrosse, and men’s ice hockey – sample numbers and age range not stated	15 year Prospectively collected data	Had to meet three criteria –resulted from playing in an organised sport game or training, required medical attention and resulted in time loss. Only concerned with injuries to metacarpals, fingers and thumbs	Phalanx injury incidence Total hand injury rate	Phalanx injury incidence 0.41/1000 AE Total hand injury incidence 0.482/1000 AE
Hendrick et al., 2008	Elite English female hockey players, sample of 110 (Age range from U20s to over 30s)	Retrospective athlete completed questionnaire reflecting their time playing hockey	No injury definition provided	Previous injury sustained	2/3rds of sample had experienced trauma to the face, mouth +/- teeth during their hockey career, over 40% had experienced more than three injuries

Continued

Study	Participants	Study Design	Injury Definition	Outcome measures	Results
Hendrickson et al., 2008	126 Division 1 female collegiate field hockey players age range not stated	Prospective recording by athletic trainers over two seasons	All head and facial injuries regardless of time loss or medical attention	Overall injury incidence Percentage and frequency rates	4.5/1000 AE for head and facial injuries 22.5% of athletes sustained a head/facial injury over the two seasons – resulting in 62 injuries over the two seasons
Junge et al., 2009	10977 registered athletes at the 2008 Olympic Games, 382 registered in hockey - age range not stated specifically for hockey but range was 15-53 years for injured athletes	Descriptive epidemiology study	Newly incurred during the Games, musculoskeletal complaint requiring medical attention, regardless of the outcome	Injury frequency in training and competition	Total injuries: 78 Hockey injuries in training: 5 Hockey injuries in competition: 67
Rishiraj et al., 2009	75 players representing British Columbia Women's Field Hockey Federation. Average age was 18 years	5 year study utilising the Sports Injury/Illness Reporting System	Medical attention with combined time loss definition – but could happen from hockey or from non-hockey activities	Injury rate Injury incidence	Combined injury rate 70/1000 game and practice exposures 67.5/1000 game hours 68/1000 practice hours
Kelly & Hudson, 2010	69 hockey players (36 male, 33 female) aged 15-18	Retrospective two season injury audit One athlete completed questionnaire to collect injury data from last two seasons, plus hypermobility measures	Any contact or non-contact injury that resulted in time-loss of at least 24 hours	Injury frequency	57 injuries over two seasons in 32 players 7 contact (2 female, 5 male) 40 non-contact (16 females; 16 males) 10 from other sports

Continued

Study	Participants	Study Design	Injury Definition	Outcome measures	Results
Mukherjee et al., 2012	324 elite junior male hockey players participating in the 2009 Junior World Cup (Age range 15-21 years)	Descriptive epidemiological study Data from direct observation of games by two observers, communication post match with physicians and the following day with physicians	Any pain, discomfort or disability in the head, face, ear or eye regions incurred from match related play that required medical attention	Incidence of head and face injuries	24 head and face related injuries from 58 matches Injury frequency was 16/1000 match hours and 19/1000 player matches 92% of the injuries were as a result of contact
Sharma et al., 2012	252 elite Indian male hockey players aged 10-30 years old	Cross sectional study Data collected through athlete completed semi-structured questionnaire	No injury definition available	Injuries reported	Goalkeepers sustained the least injuries Forwards sustained the most injuries All players reported having experienced at least one injury in either match play or training
Engebretsen et al., 2013	10568 registered athletes at the 2012 Olympic Games – specifically 388 hockey athletes, age range not stated	IOC injury surveillance study	Physical complaint resulting from match requiring medical attention, regardless of outcome	Injury frequency in training and competition	388 registered hockey athletes 66 injuries 44 in competition 18 in training Hockey in the top nine sporting codes likely to sustain an injury during the Games
Mukherjee, 2013	324 international junior male hockey players participating in the 2009 Junior World Cup (Age range 15-21 years)	Prospective epidemiology study Data from direct observation of games by two observers, communication post match with physicians and the following day with physicians	Any pain, discomfort or disability in the upper limb incurred from match related play that required medical attention	Incidence of traumatic upper limb injuries expressed per match and per 1000 match hours	28 upper limb injuries occurred during the tournament Injury incidence was 0.48.match 19/1000 match hours

Continued

Study	Participants	Study Design	Injury Definition	Outcome measures	Results
Gardner et al., 2015	Female collegiate athletes – age range not stated	Prospective data from NSAA ISS over five years	Had to meet three criteria –resulted from playing in an organised sport game or training, required medical attention and resulted in time loss. Only concerned with injuries to head, face and eyes	Injury incidence per 1000 AE for eye injuries, head/face injuries, nose injuries and dental injuries	Overall incidence of head, face and eye injuries: 0.94/1000 AE
Thielen, et al., 2015	International male and female hockey players selected for International Hockey federation tournaments - sample numbers and age range not stated	Prospective cohort study 12 months in duration. Injury data captured within match reports by match officials	Any acute injury during match play resulting in time stoppage	Average number of injuries per match Number of injuries per 1000 player match hours	0.7/match –women 1.2/match male Range of 23.4-44.2/1000 player hours female 20.8 – 90.9/1000 player hours male

AE Athlete exposures; CI Confidence Interval; IOC International Olympic Committee; NSAA ISS National Collegiate Athletic Association Injury Surveillance System;

2.5.1.1. Injury Rates. Out of the 19 field hockey studies identified, nine reported injury rates with no reference to incidence (Engebretsen et al., 2013; Freke & Dalgleish, 1994a; 1994b; Fuller, 1990; Hendrick et al., 2008; Junge, 2009; Kelly & Hudson, 2010; Murtaugh, 2001; Sharma, 2012). From the remaining ten studies, six reported injury rates in addition with injury incidence (Hendrickson et al., 2008; Junge et al., 2004; Mukherjee, 2012; 2013; Naicker et al., 2007; Thielen et al., 2015).

Injury rates ranged from a minimum of one during an elite field hockey playing career (Sharma, 2012) through to 1.2 injuries per match (Thielen et al., 2015). The spread of injury rates across the field hockey literature is large due to inconsistencies in a number of variables throughout the 19 studies. For example, study duration was wide-ranging with four studies reviewing athletes' entire hockey careers (Freke & Dalgleish, 1994a; Hendrick et al., 2008; Murtaugh, 2001; Sharma, 2012) versus five studies which investigated individual tournaments (Engebretsen et al., 2013; Junge et al., 2004; Junge et al., 2009; Mukherjee, 2012; 2013). Three of the five tournaments examined were Olympic Games, with field hockey injury rates of 16 injuries/ 1000 player hours in Athens, 204.1 injuries per 1000 registered field hockey athletes in Beijing and 170.1 injuries per 1000 registered field athletes in London (Engebretsen et al., 2013; Junge et al., 2004; Junge et al., 2009). The other two tournament studies were both based on the 2009 junior male field hockey World cup (Mukherjee, 2012; 2013). The injury rates for these two studies were much lower than those noted in the Olympic Games at 19 injuries/ 1000 match hours for upper limb and 16 injuries/ 1000 match hours for head and face injuries (Mukherjee, 2012; 2013). The focus on specific body sites investigated for injury by Mukherjee (2012; 2013) may partially explain the vast difference in injury rates recorded between the five studies. Another factor may be the intensity at which field hockey is played at in the Olympic Games compared with age group tournaments as higher match intensity would likely be associated with a greater number of injuries.

Another study reported the injury rate for one field hockey season with a rate of 0.98 injuries per player per season (Naicker et al., 2007). It is unclear how many games occur in one season and also, this study did not differentiate between training and playing injuries. It was also a retrospective study based on data collected in a stand-alone end of season injury questionnaire, which immediately makes the data susceptible to recall bias. Different study durations, injury definitions, injury rate reporting and methodologies make inter-study comparison challenging between the 19 field hockey studies.

2.5.1.2 Injury Incidence. Ten field hockey studies reported injury incidence (Bowers et al., 2008; Dick et al., 2007; Gardner et al., 2015; Hendrickson et al., 2008; Junge et al., 2004; Mukherjee, 2012; 2013; Naicker et al., 2007; Rishirai et al., 2007; Thielen et al., 2015). Injury incidence ranged from 0.41 phalanx injuries/ 1000 AE (Bowers et al., 2008) through to 70 injuries/ 1000 AE (Rishirai et al., 2007). This large range can again be attributed to methodological variations across the studies. Bowers et al. (2008) were solely concerned with hand and finger injuries that occurred during organised trainings and matches over 15 seasons, while Rishirai et al. (2007) recorded all injuries sustained in one season to all body parts, regardless of whether or not they occurred during field hockey activities. The broad injury definition employed by Rishirai et al. (2007) immediately lends itself to higher injury numbers being recorded. In addition to this broad injury definition, the close proximity and long duration of training sessions in Rishirai et al.'s (2007) sample (four hour trainings on Saturday followed by three hour trainings on Sunday) would likely have contributed to athlete fatigue, a factor which has been proposed to contribute to injury (Worrell & Perrin, 1992).

The next highest injury incidence reported is that of Junge et al.'s (2004) Athens Olympic Games study with a recorded male hockey players' injury incidence as 55 injuries/ 1000 player matches. As mentioned in the previous section, this higher injury incidence may be attributable to the higher demands of field hockey experienced on the international stage, compared with elite club or collegiate levels. Additionally, this study only looked at match injuries, and injuries are more frequent in match play than in training (Dick et al., 2007; Junge et al., 2004).

Thielen et al. (2015) investigated injury incidence over 16 international field hockey federation tournaments and they found that injury incidence for male hockey players ranged from 20.8-90.9 injuries per 1000 player hours, with an average of 48.3/1000 player hours. Again, the high injury incidence may be attributable to the level of competition investigated as all these tournaments were of an international standard and would have had influence on a country's overall ranking in hockey.

2.5.1.3. Training Injury Incidence. From the two studies which looked at training injury incidence Dick et al. (2007) found the training injury incidence to be 3.7 injuries/ 1000 training AE while Rishirai et al. (2007) had a much higher injury incidence at 68 injuries/ 1000 training AE. As mentioned previously, the schedule for training was very intense in Rishirais et al.'s (2007) study and that, coupled with their broad injury definition will have contributed to this higher training injury incidence.

2.5.1.4 Match Injury Incidence. The six studies that specifically reported match injury incidence ranged from 7.87/1000 match AE in collegiate female field hockey players (Dick et al., 2007) through to 67.5 injuries/ 1000 AE (Rashirai et al., 2007) which again was an all-female sample.

Junge et al. (2004) and Thielen et al. (2015) both had mixed gender samples in their studies. Their match injury incidences for females were 17 injuries/ 1000 player match hours and 23.4-44.2 injuries/ 1000 player match hours and 55 injuries/ 1000 player match hours and 20.8-90.9 injuries/ 1000 player match hours for male hockey players respectively (Junge et al., 2005; Thielen et al., 2015). Both studies found match injury incidence to be significantly greater in the male hockey players compared with females. This again raises questions regarding the methodology employed in Rishirai et al.'s (2007) study as it reports the highest injury incidences despite an all-female sample who were not playing at an international level.

2.5.1.5 Specific Injury Incidence. Three studies looked specifically at head, face and eye injuries (Gardner et al., 2015; Hendrickson et al., 2008; Mukherjee, 2012), one study at hand and finger injuries (Bowers et al., 2008) and one study at ankle injury incidence (Naiker et al., 2007). Head, face and eye injury incidence ranged from 0.94/1000 AE (Gardner et al., 2015) to 16/1000 match hours (Mukherjee, 2012). Gardner et al. (2015) had an all-female, collegiate level sample and looked at both trainings and match exposures over five years, compared with Mukherjee (2012) who had an all-male sample and looked solely at match exposure within one tournament. The one other study focused on head and face injury incidence reported an incidence of 4.5/1000 AE (Hendrickson et al., 2008). Although much lower than the male athlete match play incidence, it is still significantly greater than the rate reported by Gardner et al. (2015). Hendrickson et al. (2008) collected all injuries that occurred to the head, face and eye regardless of whether they resulted in time loss or not, whereas Gardner et al.'s (2015) injury definition required at least 24 hours' time lost to the injury. This means that some of the injuries captured in the study by Hendrickson et al. (2008) would not have been classified as an injury in the later study by Gardner et al. (2015).

Bowers et al. (2008) reported an injury incidence of 0.41 injuries/ 1000 AE for the phalanx and 0.482/ 1000 AE for the hand. Of note, in their study, a minimum of five days away from sport was required for an event to be classified as an injury (Bowers et al., 2008). Naicker et al. (2007) reported an ankle injury incidence rate of 1.65 ankle injuries/ 1000 player hours however this was determined for a whole season by one retrospective questionnaire, which therefore reduces the reliability of this data. If all lower limb injuries were combined, then injuries to the lower extremity were the most prevalent across all studies looking at field hockey which did not examine a particular body site (Dick et al., 2007; Fuller, 1990; Freke & Dalgleish, 1994a; Murtaugh, 2001; Sharma, 2012).

2.5.1.6 Injury Incidence related to Playing Position. Discrepancies exist between the studies as to which position gets injured more. Murtaugh (2001) reported that goalkeepers had the highest injury rate: 0.58 injuries/athlete year while midfielders had the highest injury rate for outfield players at 0.36 injuries/ athlete year. This was directly contradicted by Sharma et al. (2012) who reported goalkeepers were the least likely to get injured and that defenders were the most commonly injured in the outfield. Whereas Naiker et al. (2007) found that the positions in field hockey which sustained the most injuries in their all-female sample were the forwards and links, which again contradicts the other two studies. It is therefore hard to determine which, if any, position in field hockey is more susceptible to injury from these studies.

2.5.1.7 Surveillance Methodology. Seven of the 19 studies were retrospective in design (Freke & Dalgleish 1994 a; 1994b; Hendrick et al., 2008; Kelly & Hudson, 2010; Murtaugh, 2001; Naicker et al., 2007; Sharma et al., 2012). while the remaining 12 were prospective. From these 12 prospective studies, six looked solely at tournament play (Engebretsen et al., 2013; Junge et al., 2004; Junge et al., 2009; Mukherjee, 2012; 2013; Thielen et al., 2015) while the other six were looking at trainings and matches combined.

2.5.1.8 Limitations. As highlighted throughout this section, methodological considerations, injury definitions, study duration and study samples vary so dramatically across the 19 field hockey studies that it renders inter-study comparison very difficult. This makes it challenging to evaluate the true impact of injuries in field hockey as it is difficult to make any overall conclusions. Because of this, there is a clear and definite need for further research into both men's and women's field hockey and the impact which injury has on both sporting codes.

2.5.2 Women's Football. A literature search was carried out using Medline, Cinahl and Sports Discus databases via EBSCO as shown in Figure 2.3. The keywords were Injur* AND football OR soccer AND female* OR women*. The inclusion criteria were full original research academic journal articles, English language, published since 1990 and athletes of collegiate, professional, elite or international standard. The additional inclusion criterion of female athletes only and an additional exclusion criterion of mixed skill levels were added for football due to the large number of studies retrieved. This resulted in 14 studies to be reviewed.

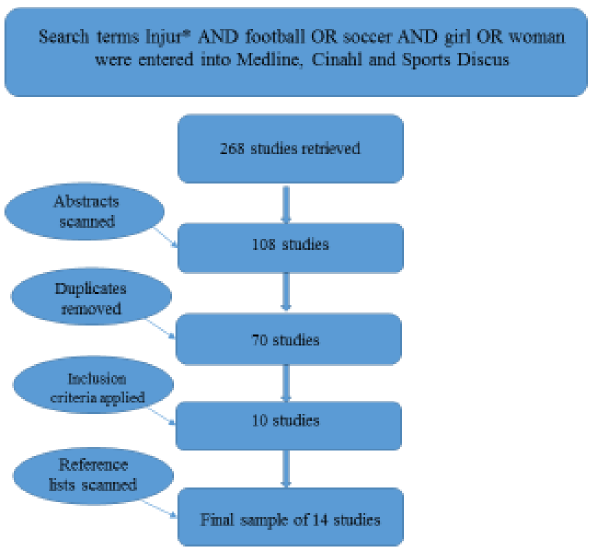

Figure 2.4 Flow diagram outlining literature search for injuries in women's football

Of the 14 articles, two investigated collegiate footballers (Dick, Putukian, Agel, Evans & Marshall, 2007; Meyers, 2013), nine studies examined professional/ elite footballers (Faude, Junge, Kindermann & Dvorak, 2005; 2006; Giza, Mithofer, Farrell, Zarins & Gill, 2005; Hartmut, Becker, Walther & Hess, 2010; Jacobsen & Tegner, 2007; Le Gall, Carling & Reilly, 2008; Nilstad, Bahr & Andersen, 2014a; 2014b; Tegnander et al., 2008) and three investigated international footballers (Junge & Dvorak, 2007; Rosenbaum et al., 2011; Tscholl et al., 2007). An overview of the review of the 14 articles is shown in Table 2.2.

Table 2.2

Overview of football studies

Study	Participants	Study Design	Injury Definition	Outcome measures	Results
Faude et al., 2005	165 females age 22.4 +/- 5.0 yrs from German National League	One season prospective cohort	Injury resulted from training or match play and resulted in a minimum of one day's time loss (NCAA-ISS definition)	Injury incidence per 1000 training and match hours	Training injury incidence: 2.8/1000hrs (2.2-3.4) Match injury incidence: 23.3/1000hrs (19.1-27.5)
Giza et al., 2005	202 female players across eight professional teams – age range not disclosed	2 seasons prospective cohort	Conditions reported to and evaluated by either the athletic trainers or team physicians	Injury incidence per 1000 player hours Training and match injury incidence per 1000 hours	Overall injury incidence: 1.93/1000hrs Training injury incidence: 1.17/1000hrs Match injury incidence: 12.62/ 1000hrs
Faude et al., 2006	143 females from German National league average 22.4 years (+/- 5 years)	One season Prospective cohort	Injury resulted from training or match play and resulted in a minimum of one day's time loss (NCAA-ISS definition)	Position specific injury incidence	Overall injury incidence goalkeepers 4.8/1000hrs (2.7-6.9) Overall injury incidence defenders 9.4/1000hrs (7.4-11.4) Overall injury incidence midfielders 4.6/1000hrs (3.3-5.9) Overall injury incidence strikers 8.4/1000hrs (6.0-10.8)
Dick et al., 2007	Collegiate female football players - age range not stated	15 year NCAA-ISS descriptive epidemiology study	Injury resulting from training or match play and resulted in a minimum of one day's time loss	Injury incidence/ 1000 AEs for training and matches	Game injury incidence 16.44/ 1000 AEs (16.00-16.88) Training injury incidence 5.23/ 1000 AEs (5.09-5.36)
Jacobsen & Tegner, 2007	269 elite female footballers from the Swedish league, age range 16-36	One season (Nov-Oct) prospective cohort study	Physical damage resulting from a football training or game resulting in absence from at least the following practice or game	Injury incidence per 1000 hours of football	Overall injury incidence: 4.6/1000hrs Training injury incidence: 2.7/1000hrs Match injury incidence: 13.9/1000hrs

Continued

Study	Participants	Study Design	Injury Definition	Outcome measures	Results
Junge & Dvorak, 2007	International female teams – sample size and age range not stated	Prospective study over 7 international tournaments	Physical complaint resulting from a match that required medical attention regardless of any time loss implications	Match injury incidence per 1000 match hours	Match injury incidence: 67.4/1000hrs (60.7-74.1) Incidence of time loss injuries: 30/1000hrs (25.2-34.8)
Tscholl et al., 2007	International female teams – sample size and age range not stated	Retrospective video analysis study over 6 FIFA tournaments	Reported by physicians using F-MARC reporting forms	Injury incidence – number of injury reports/ 1000 player hours	62.5 injuries/ 1000 player hours
Le Gall et al., 2008	119 elite female French soccer players age 15-19 years	8 season prospective study	Traumatic or overuse physical complaint resulting from organised training or match play preventing participation for at least one day post injury day	Injury incidence/ 1000 estimated hours exposure for trainings and matches	Training injury incidence 4.6/1000 training hours (4.2-5.0) Match injury incidence: 22.4/1000 match hours (19.4-25.4) Overall injury incidence: 6.4/1000 hrs Highest incidence in youngest players: 8.7/1000 hrs Lowest incidence in oldest age group: 4.9/ 1000 hrs
Tegnander et al., 2008	181 elite Norwegian footballers mean age of 23 (range 17-34 years)	One season prospective study	Time loss injury definition that occurred in organised games and trainings	Match injury incidence per 1000 game hours Training injury incidence per 1000 training hours	Acute match injury incidence 23.6/1000 game hours 3.1/1000 training hours
Hartmut et al., 2010	254 female Bundesliga players, average age 22.8 years (range 16-35 years)	One season prospective cohort study	Specific event identifiable while playing football that results in missing the rest of at least 1 game or practice	Injury incidence per 1000 playing hours	Overall injury incidence: 3.3/1000hrs (2.9-3.7) Training injury incidence: 1.4/1000hrs (1.1-1.7) Match injury incidence: 18.5/1000hrs (5.7-21.3)

Continued

Study	Participants	Study Design	Injury Definition	Outcome measures	Results
Rosenbaum et al., 2011	Women's international teams	Retrospective video analysis of two Women's World Cups	Definite injury was when player was withdrawn from the match within five minutes of the incident Apparent injury – when player goes to ground in apparent discomfort Questionable injury – when player was no removed from the field of play following going down with an apparent injury	Injury rate per game	Apparent injury rate 5.74/game Definite injury rate: 0.78/game Questionable injury rate: 4.96/game
Meyers, 2013	Female collegiate football players – sample size and age range not stated	5 year Prospective cohort	All match related injuries reported to an athletic trainer/ physician regardless of time loss	Injury incidence rate= (number of injuries/ number of team matches) X 10. IIR	Match injury incidence turf: 7.7 IRR (7.2-8.1) Match injury incidence grass: 9.5 IRR (9.3-9.7)
Nilstad et al., 2014	173 elite Norwegian female football players age range 21.5 +/- 4.1 years	Prospective cohort study	Time loss injury definition as per the consensus statement	Injury incidence/ 1000 player hours	Overall injury incidence 3.8/1000 player hours (3.2-4.4) Match injury incidence: 12.9/1000 player hours (CI 9.9-15.9) Training injury incidence: 2.6/ 1000 player hours (CI 2.1-3.1)
Nilstad et al.,2014	228 elite female footballers from 12 Norwegian teams – no age range stated	Prospective cohort study over one season	Time loss injury definition as per the consensus statement	Injury incidence/ 1000 player hours	232 time loss injuries – 62% captured via text, only 10% captured by medical staff Training injury incidence: 3.7/1000hrs from texts (3.0-4.3) Training injury incidence: 2.2/1000hrs from medical staff registration (1.5-2.8) Match injury incidence from texts: 18.6/1000hrs (14.7-22.5) Match injury incidence from medical registration: 5.4 (3.8-7.0)

AE Athletic Exposure; CI Confidence Interval; FIFA Federation International Football Association; F-MARC FIFA Medical and research centre; IIR Injury incidence rate; NCAA-ISS National Collegiate Athletic Association Injury Surveillance System

2.5.2.1 Injury Rates. Two of the 14 studies on women's football presented injury rates rather than injury incidence (Rosenbaum et al., 2011; Meyers, 2013). Rosenbaum et al., (2011) presented injury rates for World cup matches with an apparent injury rate of 5.74/ game and Meyers (2013) presented injury incidence rates (IRR) for collegiate matches. Those held on turf had an IRR of 7.7 IRR (7.2-8.1) and those on grass had a reported IRR of 9.5 IRR (9.3-9.7) (Meyers, 2013).

2.5.2.2 Injury Incidence. The remaining twelve studies all reported injury incidence (Dick et al., 2007; Faude et al., 2005; 2006; Giza et al., 2005; Hartmut et al., 2010; Jacobsen & Tegner, 2007; Junge & Dvorak, 2007; Le Gall et al., 2008; Nilstad et al., 2014a; 2014b; Tegnander et al., 2008; Tscholl et al., 2007). Six of these provided an overall injury incidence (Faude et al.,2006; Giza et al., 2005; Hartmut et al., 2010; Jacobsen & Tegner, 2007; Le Gall et al., 2008; Nilstad et al., 2014b). Overall injury incidence ranged from 1.93/1000 hours (Giza et al., 2005) through to 9.4/ 1000 hours (Faude et al., 2006) study. Giza et al. (2005) were the only study of these six, to use a medical attention injury definition, yet they reported the lowest overall injury incidence despite the fact that medical attention definitions are likely to capture greater number of injuries than time loss definition studies (Bahr & Clarsen, 2014). It is unclear why their two-season long study had such a lower overall injury incidence than other studies. Giza et al. (2005) were the only North American study out of the six that looked at overall injury incidence, with the other five clubs focusing on European playing environments

2.5.2.3 Training injury incidence. Nine studies provided training injury incidence (Dick et al., 2007; Faude et al., 2005; Giza et al., 2005; Hartmut et al., 2010; Jacobsen & Tegner, 2007; Le Gall et al., 2008; Nilstad et al., 2014a; 2014b; Tegnander et al., 2008). This ranged from 1.17/1000 hours (Giza et al., 2005) through to 5.23/ 1000 AE (Dick et al., 2007). This refutes the supposition that geographical location influenced the overall injury incidence in Giza et al.'s (2005) study as Dick et al. (2007) investigated collegiate female footballers over a fifteen year period using the NCAA-ISS database, which is based in North America. However very few methodological details are provided from Giza et al. (2005) which may have contributed in less accurate injury data. Of note is that Nilstad et al., (2014b) found that when self-reporting, their sample had a training injury incidence rate of 3.7/1000 hours compared with a rate of 2.2/1000 hours when collecting the information from physician consultations. This implies that their sample did not seek medical attention for all injuries which may partially explain why Giza et al.'s (2005) injury incidence both overall and for training is considerably lower than the other studies.

2.5.2.4 Match injury incidence. 11 studies reported match injury incidence for women's football (Dick et al., 2007; Faude et al., 2005; Giza et al., 2005; Hartmut et al., 2010; Jacobsen & Tegner, 2007; Junge & Dvorak, 2007; Le Gall et al., 2008; Nilstad et al., 2014a; 2014b; Tegnander et al., 2008; Tscholl et al., 2007). All of the studies that recorded training and match injury incidence found match injury incidence to be considerably greater than training injury incidence. Match injury incidence for female footballers ranged from 12.62/1000 hours (Giza et al., 2005) through to 67.4/1000 hours (Junge & Dvorak, 2007). For all injury incidence rates, Giza et al (2005) have consistently provided the lowest figures. Junge and Dvorak (2007) focused on injuries sustained over seven international tournaments. The intensity of matches at an international level is likely to be higher than those encountered at a collegiate or elite playing level. It may be that the higher intensity of competition results in higher match injuries. Tscholl et al (2007) was the other study that looked at international matches and their match injury incidence was also high at 62.5/1000 hours. This is very similar to that reported by Junge and Dvorak (2007) suggesting that there is a higher match injury incidence seen in international tournaments. Additionally, both of these studies used a medical attention definition, for injury, rather than a time loss and so captured all injuries reported by physicians from these matches.

2.5.2.5 Specific injury incidence. Although none of the 14 studies investigated specific injury incidence, it was possible to draw some conclusions from the data they presented. Dick et al. (2007) found that over their 15 year study, 70% of all injuries occurred in the lower limb. This finding was supported by a number of other studies (Giza et al., 2005; Jacobson & Tegner, 2007; Junge & Dvorak, 2007; Le Gall et al., 2008). Indeed, a number of the studies found that ankle injuries were one of the most common injuries in female footballers (Dick et al., 2007; Giza et al., 2005; Hartmut et al., 2010; Jacobson & Tegner, 2007; Junge & Dvorak, 2007; Tscholl et al., 2007).

2.5.2.6 Injury incidence related to playing position. As with field hockey, discrepancy exists regarding which position is reported to experience the highest injury incidence. Faude et al. (2006) found midfielders were injured the least and defenders the most. This is in direct contrast to Giza et al. (2005) who noted that midfielders were the most commonly injured. Meyers (2013) found that there were no differences in injuries between offensive and defensive positions. It is therefore hard to draw conclusions regarding which position is most impacted by injuries in women’s football.

2.5.2.7 Surveillance methodology. There were only two from the 14 studies investigating women’s football that did not use a prospective design. These were Tscholl et al. (2007) and Rosenbaum et al. (2011). Both of these studies used retrospective video analysis. Tscholl et al. (2007) used video analysis of matches, in conjunction with the FIFA regulation injury forms completed daily by team physicians in international tournaments. Rosenbaum et al. (2011) also used video analysis of past international tournaments, however, they did not utilise medical forms, they simply investigated whether injury breaks resulted in player substitution, medical attention or whether it seemed to be a simulated event linked with gamesmanship. Although both of these studies were retrospective in nature, the risk of recall bias was limited because they were using historical records and videoed matches. It did mean that if there were any discrepancies or confusion, people could not be contacted for clarification on issues as recall would be poor.

The other twelve studies all completed their investigations for a minimum of one season/ year while the longest prospective study was run over a 15 year period (Dick et al., 2007). The high number of prospective studies facilitates greater inter study comparison.

2.5.2.8 Limitations. Compared with hockey, there is greater homogeneity across the football studies. While there are still differences in injury definition, it is clearly stated in the studies whether they used a time loss or a medical attention definition. The time loss definition only has two variables across the studies – it is either for at least one day following the injury, or, in the case of Hartmut et al. (2011) the rest of that game/ training session.

It is suspected by the author that the publication of the football consensus statement (Fuller et al., 2006) has helped to reduce variations in definitions and methodologies across the studies and therefore has yielded a number of high quality prospective studies investigating injury incidence in women’s football thus allowing for greater inter-study comparisons. However, none of the studies focuses on Southern hemisphere teams and therefore data is required to determine whether injury incidence in New Zealand’s national team is comparable to that documented in published literature.

2.5.3 Kayak. A literature search was carried out using Medline, Cinahl and Sports Discus databases via EBSCO as shown in Figure 2.4. The keywords were Injur* AND flatwater AND kayak. The inclusion criteria were full original research academic journal articles, English language, published since 1990 and athletes of collegiate, professional, elite or international standard. The published research for flatwater kayaking is very limited with only five studies being identified for review, the overview of which can be found in Table 2.3.

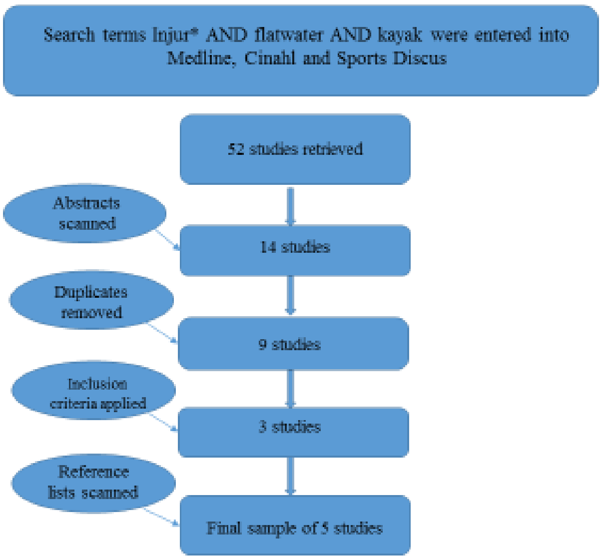

Figure 2.5 Flow diagram outlining literature search for injuries in kayak

Two of the five articles on kayaking were focused on injury surveillance of all sports in the 2012 and 2008 Olympic Games (Engebretsen et al., 2013; Junge et al., 2009). One article was a case study on an elite flatwater sprint kayaker (Piasecki, Meyer & Bach, 2008) and the other two were concerned with elite Swedish and British flatwater kayakers respectively (Johansson, Svantesson, Tannerstedt & Alricsson, 2016; Lovell & Lauder, 2001). Lovell and Lauder (2001) investigated contralateral limb strength differences in relation to injured and non-injured kayakers and Johansson et al. (2016) focused on shoulder pain in their Swedish kayaking population.

Table 2.3

Overview of kayaking studies

Study	Participants	Study Design	Injury Definition	Outcome measures	Results
Lovell & Lauder (2001)	30 national-international flatwater kayakers (9 women and 21 men) mean age of 25 years (SD 6)	Retrospective cohort study	Time loss equal or greater than 5 days from training– subdivided into trunk or upper limb	Retrospective injury frequency review from the previous 6 months compared with bilateral peak-force strength measures	Injured groups were found to have greater strength deficits than the non-injured group. – this was significant in the upper limb injured group
Piasecki et al. (2008)	27 year old flatwater kayaker	Case study	Exertional related forearm pain, swelling and paraesthesia	Symptom provocation with training	Post fasciotomy, the athlete returned to training symptom free
Junge et al. (2009)	10977 registered athletes at the 2008 Olympic Games, 324 registered in kayak and canoe – age range not stated	Descriptive epidemiology study	Newly incurred musculoskeletal complaint that resulted in medical attention	Total number of injuries	4 reported injuries all of which occurred in training

Continued

Study	Participants	Study Design	Injury Definition	Outcome measures	Results
Engebretsen et al. (2013)	10568 registered athletes at the 2012 Olympic Games, 249 registered in canoe sprint – age range not stated	Descriptive epidemiology study	New or recurring musculoskeletal complaints that required medical attention	Total number of injuries	7 reported injuries, 3 from training and 3 from competition. One of these injuries resulted in time loss
Johansson et al. (2016)	31 competitive flat water Swedish kayakers (11 females mean age 16.6 (SD 1.4), 20 males mean age 18.2 (SD 3.0))	Retrospective questionnaire with current shoulder assessment	Pain in the shoulder	Shoulder questionnaire	45.2% of sample had experienced shoulder pain in the last year 54.8% (17/31) of sample had experienced shoulder pain at some point

2.5.3.1 Injury rate. Upper limb injuries resulted in 29.8 days lost (SD:17) and trunk injuries resulted in 66.7 days lost (SD 31.4) in elite British flatwater kayakers over a six month period (Lovell & Lauder, 2001).

Piasecki et al (2008) presented a case study. While this does not intimate injury incidence or prevalence in flatwater kayaking, it does highlight that one injury presentation in the sport can be chronic exertional compartment syndrome of the forearm.

Junge et al. (2009) performed injury surveillance during the 2008 Olympic Games. Kayaking was one of only five sports in the event which sustained no inter-competition injuries and had no time loss injuries however, out of 324 registered flatwater kayakers, four medical attention injuries were sustained during training. Engebretsen et al. (2013) performed a similar study for the London Olympics. 249 canoe sprint athletes were registered and sustained 7 injuries over the course of the Games. One was a time loss injury. Three of the injuries occurred in training and the other three occurred in competition. Again kayak was one of the five sports in the London Games with the lowest relative injury risk.

Johansson et al. (2016) did not define injury – but used a retrospective questionnaire to discover if kayakers had experienced shoulder pain. A limitation of their study is that it relies on retrospective data from the athletes which may mean that some episodes of shoulder pain may have been omitted. The lack of injury definition also limits the inter study comparison of this study with others. Male kayakers were more likely to report shoulder pain than their female counterparts. Nine athletes had medical attention for their shoulder pain while 12 had modified or missed training/competition sessions. Kayakers who had experienced shoulder problems in the last three years were found to have a reduced range of movement of the shoulder and a risk ratio of 3:1 of having scapular dyskinesis compared with the kayakers who had not had shoulder pain.

These five articles are variable in their methodology. The two studies from the Olympic Games provide us with little detail but do demonstrate the low levels of injuries sustained in flatwater kayaking in competition. This may in part explain why there is so little published information surrounding kayak injury incidence and prevalence. From the three articles which specifically mention complaints, upper limb and trunk injuries appear to be the most prevalent although injury incidence has not been defined for the sport.

2.5.3.2 Injury incidence. None of the studies presented injury incidence.

2.5.3.3 Training injury incidence. None of the studies presented training injury incidence.

2.5.3.4 Match injury incidence. None of the studies presented match injury incidence.

2.5.3.5 Specific injury incidence. While none of the studies reported specific injury incidence, there appears to be consensus that the upper limb is the most common area injured with kayaking (Johannson et al., 2016; Lovell & Lauder, 2001).

2.5.3.6 Injury incidence related to kayak discipline. None of the studies mentioned any position specific injuries or injury incidence.

2.5.3.7 Surveillance methodology. Two of the studies were prospective, looking at kayaking injuries in the Olympic Games (Engebretsen et al., 2013; Junge et al., 2009), two were retrospective studies (Johannson et al., 2016; Lovell & Lauder, 2001) and the final study was a case study on an individual elite athlete.

2.5.3.8 Limitations. Injury definition varied considerably between the studies making it hard to compare the findings from different studies. Lovell and Lauder (2001) used a time loss injury definition for a minimum of five days, the two Olympic studies used a medical attention definition (Engebretsen et al., 2013; Junge et al., 2009) and Johannson et al. (2016)

defined an injury as pain in the shoulder regardless of outcome. No exposure data was collected by any of the studies. This paucity of quality injury data highlights the need for further investigation into the impact of injury on flatwater kayaking.

2.5.4 Sailing. A literature search was carried out using Medline, Cinahl and Sports Discus databases via EBSCO as shown in Figure 2.5. The keywords were Injur* AND sail* OR yacht*. The inclusion criteria were full original research academic journal articles, English language, published since 1990 and athletes of collegiate, professional, elite or international standard. This resulted in seven sailing studies being identified for review, an overview or which can be found in Table 2.4.

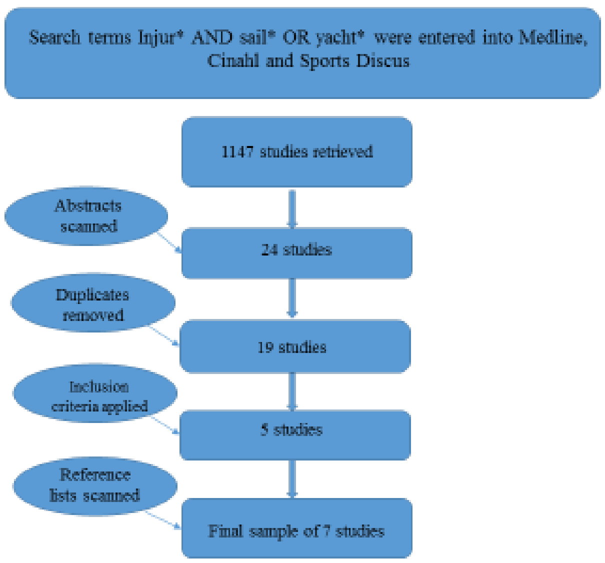

Figure 2.6 Flow diagram outlining literature search undertaken for injuries in sailing

Four of the seven studies' samples were solely comprised of elite Olympic sailors (Engebretsen et al., 2013; Junge et al., 2009; Legg et al., 1997 and Tan, Leong, Vaz Pardal, Lin & Kam, 2016), two studies had mixed samples (Bøymo-Having, Grävare & Silbernagel

2013; Nathanson, Baird & Mello, 2010) and the seventh study sample was made up of 43 certified yachting instructors from Korea (Hamm & Jee, 2016).

Table 2.4

Overview of sailing studies

Study	Participants	Study Design	Injury Definition	Outcome measures	Results
Legg et al. (1997)	28 elite New Zealand sailors (22 male, 6 female)	Retrospective questionnaire	No injury definition	% of sailors who had experienced an injury	4/28 (14%) had a current injury 16/28 (57%) reported an injury in the last three years. 45% were to the back, 18% to the shoulder and 15% to the arm
Junge et al. (2009)	10977 registered athletes at the 2008 Olympic Games, 400 registered in sailing, age range not stated	Descriptive epidemiology study	Newly incurred musculoskeletal complaint that resulted in medical attention	Total number of injuries	3 reported injuries 1 from training and 2 from competition
Nathanson et al. (2010)	1188 sailors ranging from beginner through to professional with average age of 40.1 (SD 13.2, range 18-80)	Retrospective questionnaire surveillance study	No injury definition	Total number of injuries and anatomical site	1715 reported injuries over the previous 12 months. 71% from keel boats and 23% from dinghies. Most common injury types were contusions, lacerations and sprains Most common sites: Keel boats: upper extremity (40%), lower extremity (38%) and trunk (11%). Dinghies – lower extremity (44%), upper extremity (38%) and head/neck (12%) Incidence of 0.2 injuries/athlete/year
Bøymo-Having et al. (2013)	45 sailors (28 men; 17 women) 24 were elite sailors mean age 23 (SD 3.79) and 21 were club sailors mean age 17 (SD 1.3)	Prospective cohort study over 12 months	A musculoskeletal complaint resulting from either trauma or overuse	Number of injuries	144 injuries over 12 months 79 in the elite sailors and 65 in the club sailors

Continued

Study	Participants	Study Design	Injury Definition	Outcome measures	Results
Engebretsen et al. (2013)	10568 registered athletes at the 2012 Olympic Games, 380 registered in sailing, age range not stated	Descriptive epidemiology study	New or recurring musculoskeletal complaints that required medical attention	Total number of injuries	56 reported injuries, 18 from training and 30 from competition. Four of these were time-loss injuries
Hamm & Jee (2016)	43 male yacht instructors mean age 46.28 (SD 9.6)	Retrospective self reported questionnaire	No injury definition	Reported injuries	30 injuries
Tan et al. (2016)	760 Olympic class sailors, age range not stated	Retrospective 12 month questionnaire and prospective surveying during World Champs	Newly incurred musculoskeletal complaint that resulted in medical attention	Injury prevalence and incidence	12 months: 0.59 injuries/ 1000hrs sailing 32% injury prevalence 64% of injuries occurred on the water during training, 31% during races and 14% during land training In competition: 4 injuries/ 1000 days of sailing

Three of the seven studies investigated sailing injuries in elite competition. Two focused on Olympic Games while Tan et al. (2016) focused on the 2014 Sailing World Championships.

2.5.4.1 Injury rates. Tan et al. (2016) reported an injury rate of 32% while Nathanson et al. (2010) documented 1715 injuries in their study. The difference in reporting methods between the two studies makes comparison very difficult. The two Olympic studies both used medical attention injuries and recorded the number of injuries over the tournament (Engebretsen et al., 2013; Junge et al., 2009). At the 2008 Beijing Olympics, there were only three injuries for the 400 registered sailors for the entirety of the Games (Junge et al., 2009). Four years later, in a sample of equivalent size (380 registered sailors), 56 injuries were documented, more than 15 times that at the previous Olympics (Engebretsen et al., 2013). Whether this increase in recorded injuries was due to environmental conditions, improved reporting or greater competitiveness within the sport is not known, as they are not documented. Additionally, it is not specified in either study in which boat type the injuries occurred or any athlete demographics.

2.5.4.2 Injury incidence. Injury incidence was presented by two studies and ranged from 0.2 injuries/athlete/year (Nathanson et al., 2010) through to 4 injuries/ 1000 days of sailing (Tan et al., 2016). Tan et al. (2016) collected their data prospectively during the 2014 Sailing World Championships whereas Nathanson et al. (2010) used a retrospective survey to recall injuries over the preceding 12 months.

The higher injury incidence reported in the elite sailing event corresponds with the findings of Bøymo-Having et al. (2013) who found a trend that the elite sailors in their sample were injured more frequently than the club sailors. This could be because greater sailing skill levels result in faster sailing, therefore increasing the likelihood of an injury occurring, however it did not reach statistical significance. Nevertheless, the retrospective methodology employed by Nathanson et al. (2010) does render their results subject to recall bias, and therefore some injuries may not have been captured.

2.5.4.3 Training injury incidence. No study specifically reported training injury incidence, however the two surveys that collected injury data from the Olympic Games noted that 1 from 3 recorded injuries and 18 from 56 occurred in training in the 2008 and 2012 Games respectively (Junge et al., 2009; Engebretsen et al., 2013). This suggests that more injuries occur in match racing scenarios than in training environments for sailing.

2.5.4.4 In-competition injury incidence. Tan et al. (2016) reported an in-competition injury incidence of 4 injuries/ 1000 days of sailing. The two Olympic studies found 2/3 and 30/56 injuries occurred in competition in the 2008 and 2012 Olympic Games respectively (Junge et al., 2009; Engebretsen et al., 2013). None of the other studies reported specific in-competition injury incidence however, Nathanson et al. (2010) did note that 79% of the 1715 reported injuries in their study did occur during racing.

2.5.4.5 Specific injury incidence. From the seven studies reviewed, five identified the site of injury. Two of these studies concluded that the lumbar spine was the most commonly injured region of the body in sailing (Legg et al., 1997; Tan et al., 2016) and the other three found the lower extremity to be most commonly injured (Bøymo-Having et al., 2013; Ham & Jee, 2016; Nathanson et al., 2010).

The prospective study undertaken at the International Sailing World Championship found that in competition, the most commonly injured body part were the hands/ fingers (15/67) – followed by back (12/67) and then foot (8/67) (Tan et al., 2016). Despite the apparent contradiction between the studies as to whether lumbar spine or lower extremity were more commonly injured, all five studies had both regions in their top three most commonly injured body sites from sailing.

Sailing was also found to have a lot of injuries that resulted from overuse. Bøymo-Having et al., (2013) found that 30 of their recorded injuries were traumatic in origin while the other 114 were attributed to overuse although no further details were provided. This is a similar finding by Tan et al. (2016) who noted overuse injuries were the most common resulting in 58% of the injuries with traumatic causes causing 28%

2.5.4.6 Injury incidence related to sailing class. The following sailing classes frequently reported low back pain: 470 men, 470 women, Finn and RS:X men (Tan et al., 2016). The 470 men were most likely to experience low back pain at 63% while laser standard sailors had more ankle injuries than any other class (Tan et al., 2016). Nathanson et al. (2010) found that 71% of the recorded 1715 injuries occurred in keel boats and 23% of injuries occurred in dinghies. None of the other studies specified in what class of boat injuries occurred.

2.5.4.7 Surveillance methodology. Four of the seven studies used retrospective methodology (Bøymo-Having et al., 2013; Ham & Jee, 2016; Legg et al., 1997; Nathanson et al., 2010). Tan et al. (2016) had a twelve month retrospective survey as part of their study, but then their in-competition injury surveillance was prospective in design. Junge et al. (2009) and Engebretsen et al. (2013) both used a prospective design in their studies. Tan et al. (2016) then used the same injury definition as the two Olympic Games studies to facilitate inter study comparisons.

One of the studies that used a retrospective design reduced the likelihood of retrospective issues by having the sailors complete a web based questionnaire monthly (Bøymo-Having et al., 2013). While still relying on accurate recall and reporting from the sailors, it is more likely to have greater reliability than the method employed by Legg et al. (1997) which asked athletes to recall any injuries they had sustained in the previous three years. They also tried to reduce recall problems by issuing athletes with training diaries at the start of the study, which they had to complete daily. This written record would then help with remembering injuries and how much time was lost from training because of them.

2.5.4.8 Limitations. As with the other three sports, the use of retrospective methodology reduces the reliability of four studies' results, as documented in the previous section. Variability around injury definitions existed in the seven sailing studies. While three studies used the same medical attention injury definition (Engebretsen et al., 2013; Junge et al., 2009; Tan et al., 2016), three other studies did not provide any injury definition (Ham & Jee, 2016; Legg et al., 1997; Nathanson et al., 2010) and the remaining study by Bøymo-Having et al. (2013) used an all-encompassing injury definition regardless of time loss or medical attention. This again leads to the conclusion that further robust injury research is required in the sport of sailing to provide a clearer picture of the impact of injury on the sport

2.5.5. Summary. The quality of injury surveillance studies varies dramatically across the four sports that this study will investigate. Women's football studies had the greatest homogeneity, resulting in easier between study comparisons whereas the quality of studies published across the other three sports was highly variable. Football is a very well structured and funded sport worldwide, which has a designated medical and research committee which helps to drive the publication of high quality studies (Fuller et al., 2006). The existence of a consensus statement regarding the publication of football injury surveillance also helps to ensure rigour in football studies. The other three sports do not have the same structures in place. Additionally, while hockey is similar to football in terms of regular weekly fixtures, both sailing and kayaking have dramatically fewer competitions with maybe two or three pinnacle events a year. While this may make injury surveillance easier for competitions, rather than having to collect weekly data, it does rely on the governing bodies to ensure the promotion and uptake of injury surveillance at these key events.

Only one study across the four sports was specifically concerned with New Zealand athletes and that was Legg et al. (1997). This study's methodology is imprecise due to its retrospective nature and the long time period (over three years) that it attempted to examine. All the football studies were based on European or American athletes with none completed by Southern hemisphere countries. Whereas the hockey studies were again concerned with European or American athletes as well as Indian athletes. Those studies that looked at International results such as Olympics or World Championships did not specifically mention athletes from different countries. Therefore, there is an opening for injury surveillance in elite New Zealand athletes across these four sporting disciplines. This fact, coupled with the unknown reliability of the HPSNZ PILLS tool presents an opportunity for a research project into elite HPSNZ athletes in women's football, men's and women's hockey, flat water kayaking and sailing. The structure and design of this study will be outlined in the following chapter.

3 Methods

Introduction

The sample under investigation for this study was HPSNZ carded athletes. All NSOs based in Auckland were approached for participation and the five sports of men's hockey, women's hockey, women's football, flat water kayaking and sailing agreed. Injury and training data for these athletes was captured using the HPSNZ PILLS app which was completed weekly over a twelve-month period from May 2011 through to April 2012. This chapter will outline how this process occurred.

3.1 Study Design

This study was a twelve-month longitudinal prospective cohort study.

3.2 Participants

Ethical approval was not required for this study as carded athletes provide consent for anonymised data to be used for research purposes in their athlete contracts. Nevertheless, to ensure transparency, and to ensure that athletes were aware of the study, a separate consent form was issued to them regarding their inclusion in the "Programme for Injury and Illness Surveillance (PILLS)," the use of the PILLS monitoring app and inclusion in this study (Appendix B).

The principal researcher (JS) advised the physiotherapists employed with the respective NSOs about the study and provided all NSOs with a PILLS consent form (Appendix B) and a modified Oslo Sports Trauma Research Centre (OSTRC) questionnaire (Appendix C). The physiotherapist from each NSO outlined the study to the coaches and athletes and distributed the consent forms. Those who completed the consent form were then asked to complete the OSTRC questionnaire. On receipt of the completed written consent forms and OSTRC questionnaires, unique identification numbers were allocated to all athletes to ensure that their data remained anonymous.

Inclusion criteria for the study was any carded athlete involved with the four identified NSOs of women's football, men and women's hockey, kayak and the age group sailors. If, during the course of the study, the athlete became de-carded for any reason, or they did not have a phone or tablet, then they were excluded from the study.

3.3 Measurements

3.3.1 OSTRC. A modified version of this questionnaire was issued to participants once they had completed their consent form (see Appendix C). This was to record any pre-existing complaints that may have been restricting participation in their sport from the start of the study. It was only completed at the beginning to obtain baseline injury prevalence and to ensure compliance with the PILLS survey was not compromised due to too many demands being put on the athletes.

3.3.2 PILLS weekly survey. This study investigated the weekly self-reported injury surveillance questionnaire developed and implemented by HPSNZ known as the PILLS app. Although the PILLS app also collects illness data, it was decided to only focus on injury data for the purpose of this study. The questionnaire was ready for completion each week by the athletes who had to open the application on their smart device in order to complete the questionnaire. The questions and lay out of the survey are available in Appendix A. Each physiotherapist allocated to the specific sports was responsible for following up with individual athletes if they had not completed it and up to two reminders a week were issued either by email or in person.

The results from each week's surveys were captured in a central database linked with the software package and the results were sent to the principal researcher on a monthly basis.

3.3.3 Exposure estimates. The PILLS questionnaire captured planned, missed and modified trainings however it did not capture the duration of these trainings. To allow for this, each strength and conditioning coach for the NSOs, who attended each session, provided an estimate of how long an average training session lasted. For women's football, women's hockey and kayaking it was 2 hours, while the average duration for men's hockey was 1.5 hours.

Exposure estimates were therefore calculated as follows for each NSO:

$$Number\ of\ reported\ completed\ trainings\ x\ average\ training\ duration \div number\ of\ completed\ surveys\ that\ week$$

These totals were then added up for the relevant number of weeks in any given month to achieve a monthly average exposure estimate per NSO. The only exception was sailing who, as an NSO utilise a software package called TrainingPeaks™. This package records actual daily training times but relies on athlete completion. There was a large variability in the compliance of the sailors to complete training peaks so average exposure estimates were again used. These were calculated as follows:

$$Total\ number\ of\ training\ hours\ reported \div number\ of\ sailors\ who\ completed\ training\ peaks\ that\ week$$

Again, the weekly totals were combined to produce a monthly average exposure estimate.

3.4 Definitions

Because of the limited consensus in methodology and definitions in the literature across the five sports, a pragmatic approach was undertaken in this study.

3.4.1 Injury definition. The definition for an injury was adapted from Fuller et al.'s work (2006; 2007) to be, "Any physical complaint, which was caused by a transfer of energy that exceeded the body's ability to maintain its structural and/ or functional integrity, sustained by an athlete during competition or training in their chosen sport resulting in one or more sessions being missed or modified." (p.329).

3.4.2 Injury classification. Injuries were classified as acute, recurrent or exacerbations. Acute injuries were new or index injuries that occurred during the study period, recurrent injuries had occurred before but from which the athlete had returned back to full training prior to it becoming problematic again, and exacerbations were where athletes had returned to training but with modifications, before missing further trainings because of the same injury.

3.4.3 Injury incidence. Injury incidence was defined as the number of injuries per 1000 hours of athlete exposure as recommended by Junge et al. (2006).

3.4.4 Injury prevalence. Injury prevalence was defined as the number of injuries within the sample divided by the total sample population (Büttner & Muller, 2015).

Point prevalence was used at the start of the study, and then period prevalence was used for all other reporting purposes (Büttner & Muller, 2015).

3.4.5 Injury duration. This was captured using the number of training weeks lost. It started from the week of the injury and finished when the athlete was able to complete a PILLS survey having trained fully. One week or less was graded as a minor injury, two to six weeks was classified as a moderate injury and over six weeks of missed or modified trainings was considered a severe injury.

3.4.6 Compliance. This was the number of surveys completed by each individual out of a possible 52. Even if response rates were low, all data was included for each individual athlete.

3.5 Data analysis

To ensure there were no extreme outliers, all demographic data was initially analysed descriptively for normal distribution. Continuous variables of height, age and weight were reported with their means and standard deviations. To determine survey compliance, injury frequency, injury incidence and injury prevalence, descriptive analyses were used. These were presented for the individual sports and comparing the five separate groups. For sailing and kayak, descriptive analyses alone were used due to the small numbers of their samples.

Chi squared analysis was used for women's football, women's and men's hockey to determine injury frequency per body site. A linear regression model was constructed to determine whether there was any relationship between injury frequency and training load for these three sports. All statistical analysis was undertaken using the Statistical Program for Social Science (SPSS) (IBM SPSS Inc, Chicago) Version 23 with alpha levels set at 0.05 (95% confidence level).

4 Results

Introduction

This chapter is divided into three sections. The first section outlines the subjects for this study, the second section highlights the results from the injury surveillance that was undertaken for 52 weeks and the final section presents the results of the correlation analysis between injury frequency and training exposure.

4.1 Subjects.

A total of 124 athletes met the inclusion criteria for this study. Male hockey players made up 36 of the sample, 36 were female hockey players, 29 were female women's football players, 14 were flatwater kayakers and 9 were sailors. All were carded athletes in the HPSNZ environment and all completed the consent form and OSTRC baseline questionnaire. Nine athletes did not complete the study, seven were decarded over the twelve month period and two athletes lost/damaged their smart devices and did not replace them within a timely manner so therefore could not complete any further PILLS surveys. This left a final sample of 33 male hockey players, 34 female hockey players, 26 female footballers, 13 kayakers and 9 sailors totalling 115.

The sample was made up of 38.8% male athletes and 61.2% female athletes with an age range of 16 to 39 years (mean 23.48, SD: 4.11). Descriptive analysis of the data demonstrated normal distribution, therefore an independent t-test was employed. No significant difference was found for age between the male and female subjects ($p>0.05$). However, a significant difference was noted for height and weight between the male and female subjects ($p<0.05$). This can be seen in Table 4.1

Table 4.1

Demographic data for the entire study sample

	Total (SD) n=116	**Female athletes (SD) n=70**	**Male athletes (SD) n=45**	***t*-Test Significance (p<0.05)**
Mean Age	23.48 (4.11)	22.96 (4.15)	24.22 (3.97)	0.16
Mean Height	138.52 (70.52)	168.81 (6.32)	179.98 (5.13)	<0.01*
Mean Weight	70.24 (8.56)	65.75 (6.49)	77.34 (6.32)	<0.01*

*Statistically significant at p<0.01

To investigate any differences between the five sports under investigation, a one-way ANOVA was run, this found significant between group differences for all three criteria – age, height and weight ($p<0.05$) as shown below in Table 4.2.

Table 4.2

Demographic data for specific sports

	Men's Hockey (SD) n=33	**Women's Hockey (SD) n=34**	**Women's Football (SD) n=26**	**Kayakers (SD) n=13**	**Sailors (SD) n=9**	**ANOVA Significance (p<0.05)**
Mean Age	25.42 (3.38)	23.00 (3.20)	23.03 (5.47)	23.76 (2.89)	18.66 (1.11)	<0.01*
Mean Height	179.54 (5.22)	169.11 (5.89)	167.51 (6.41)	176.00 (8.49)	177.60 (7.00)	<0.01*
Mean Weight	77.24 (5.42)	66.13 (5.73)	64.00 (6.22)	74.79 (11.25)	72.24 (6.30)	<0.01*

*Statistically significant at p<0.01

4.2 Results of 52 Weeks of Injury Surveillance

4.2.1 Compliance. Table 4.3 demonstrates the significant difference in compliance between the female and male subjects as revealed by an independent t-test. Female subjects had a significantly greater compliance rate than their male counterparts ($p<0.01$). Compliance was determined as the mean number of surveys completed by each individual athlete over the 52 weeks, divided by the number of individuals either in that gender classification, or within the NSO.

Table 4.3

Compliance with PILLS

	Female athletes Percentage Compliance (SD)	Male athletes Percentage Compliance (SD)	T-test Significance (p<0.05)
Mean Compliance	72.92 (27.31)	48.35 (22.10)	<0.01*

*Statistically significant at p<0.01

Between sport comparison of compliance also demonstrated a significant difference (p<0.01) when analysed using a one-way ANOVA as indicated in Figure 4.1.

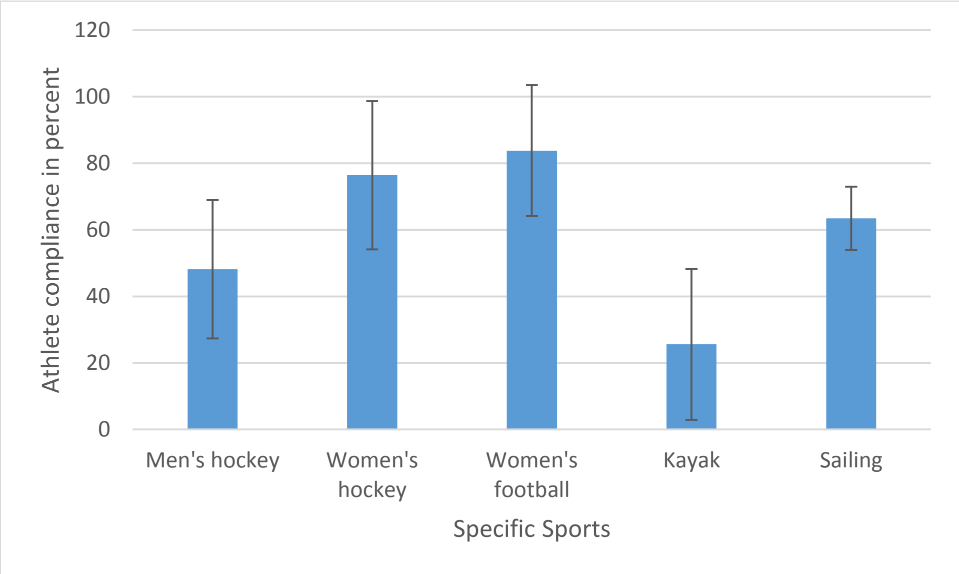

Figure 4.1 Average annual compliance rates for the five specific sports

Women's football had an average compliance of 83.79% (SD 19.66) with women's hockey being the next closest with 76.42% (SD 22.27). The poorest sport at complying with PILLS was kayak with an average compliance rate of 25.60% (SD 22.65) with men's hockey being the next poorest with a compliance rate of 48.15% (SD 20.77).

All 116 completed the OSTRC at the start of the study, the findings of which are outlined in Figure 4.2. For both women's football and kayak, approximately 50% of their sample declared an injury at the start of the study with 14 out of 27 and 7 out of 13 reporting an injury on the OSTRC respectively. Sailing had an initial injury rate of 33% with three of their sample of nine reporting any issues. Men's hockey had 36.36% of their athletes declare an injury whereas women's hockey had the greatest percentage of injuries reported with 58.82% of their athletes (20/34) declaring injury status at that point in time.

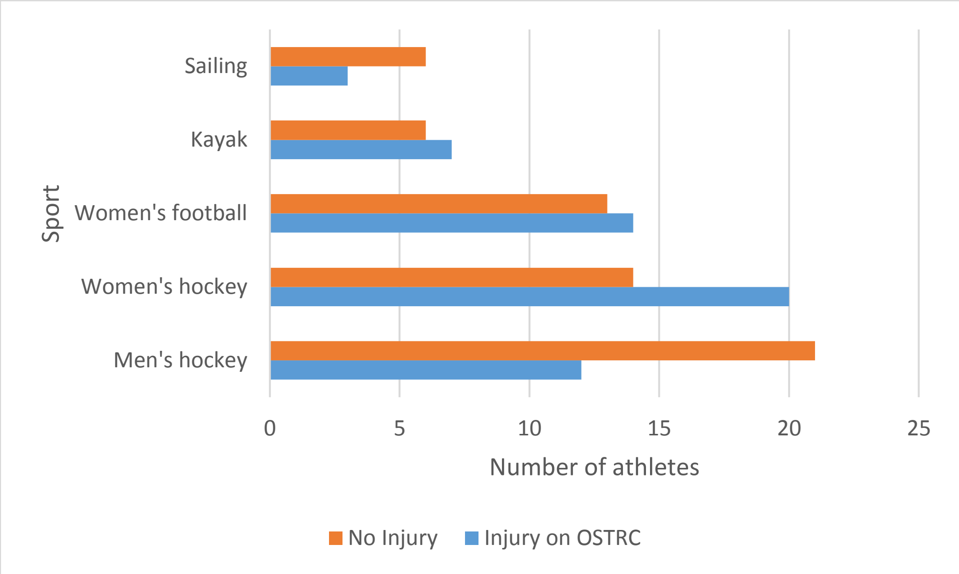

Figure 4.2 Baseline OSTRC findings per sport

4.2.2 Total Injuries. Over the twelve months, 328 time loss injuries were prospectively recorded across the sample of 116 athletes. The number of time loss injuries reported by the athletes over the five sports ranged from zero to nine. From the total study sample, 25% reported no time loss injuries during the study (n=29), while 3.4% of the total sample reported nine separate time loss injuries (n=4). This means that the 328 time loss injuries were sustained by 87 athletes over the twelve months, which is an average of 3.77 injuries per athlete. However, the injuries were not evenly spread across athletes or sports. Table 4.4 shows the average number of injuries per sport over the study duration.

Table 4.4

Average Number of Injuries Per Sport

	Men's Hockey Mean Injury Frequency (SD) n=33	**Women's Hockey Mean Injury Frequency (SD) n=34**	**Women's Football Mean Injury Frequency (SD) n=27**	**Kayakers Mean Injury Frequency (SD) n=13**	**Sailors Mean Injury Frequency (SD) n=9**
Mean number of injuries	3.27 (1.60)	4.58 (2.59)	3.25 (2.63)	2.00 (1.52)	2.33 (1.93)

Figure 4.3 outlines the distribution of these injuries across the five sports over the twelve months. Women's hockey had the highest number of injuries at 145, men's hockey had 90 and women's football reported 67. The two non-contact sports of kayaking and sailing had 14 and 12 respectively.

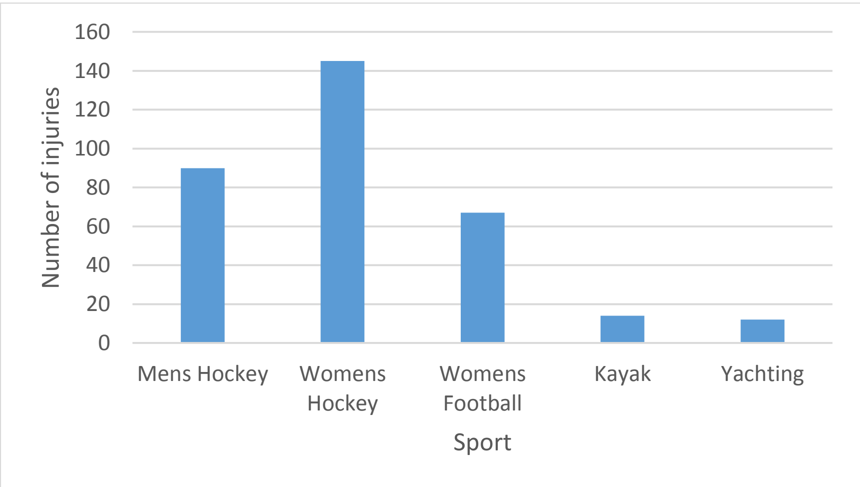

Figure 4.3 Total injuries per sport over the 12 months

The highest monthly injury count, which totalled 20 injuries in both men and women's hockey, occurred in August and September respectively as shown in Figure 4.4. Both women's hockey and women's football had injury spikes in the first month of the study with injury counts of 19 and 11 respectively. Sailing had a spike in July with 4 injuries, while kayak incurred 5 injuries in the month of December. As previously reported in the literature, the three contact sports had much higher injury numbers than either sailing or kayaking

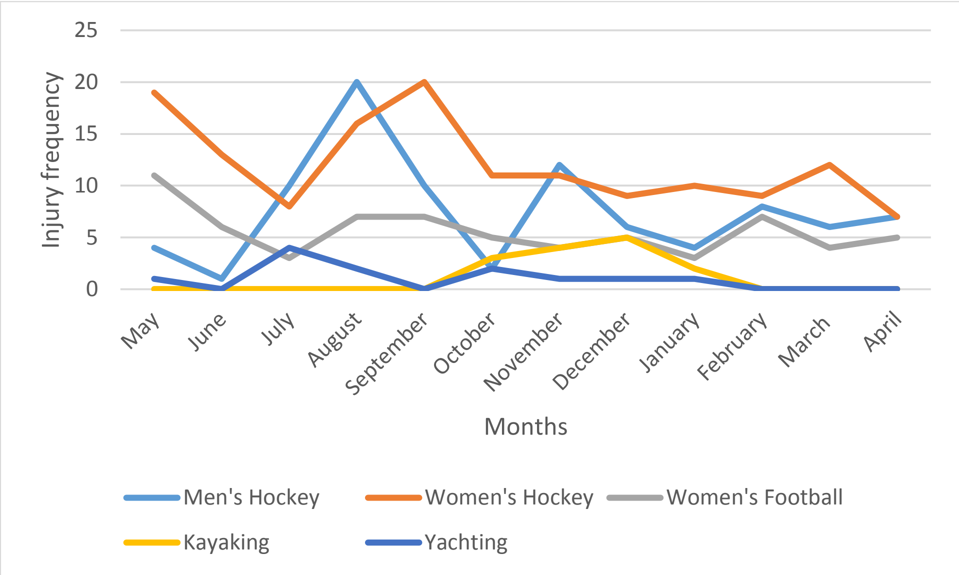

Figure 4.4 Injury count per month per sport

Table 4.5 outlines the average monthly number of time loss injuries sustained by each of the five sports and the correlating injury prevalence per month per sport. Women's hockey recorded the highest average number of timeloss injuries per month and the highest monthly injury prevalence, with men's hockey recording the second greatest in both categories.

Table 4.5

Average Number of Time Loss Injuries per month per sport

	Monthly average timeloss injuries (SD)	**Average monthly injury prevalence**
Men's Hockey	7.5 (5.14)	0.22
Women's Hockey	12.08 (4.20)	0.35
Women's Football	5.58 (2.23)	0.20
Kayak	1.16 (1.85)	0.08
Sailing	1 (1.20)	0.11

Table 4.6 shows the distribution of timeloss injuries across the various body sites for the five sports. The most commonly injured body sites were thighs in men's hockey, low backs in

women’s hockey and kayaking, ankles and feet in women’s football and knees and ankles in sailing.

Table 4.6

Time loss injury count per body site per sport

Sport	Ankle/ Foot	Lower Leg	Knee	Thigh	Hip	Low back	Mid back	Neck	Head/ Face	Shoulder	Upper arm	Elbow	Forearm	Wrist/ hand	Not Stated
Men's hockey	5	9	11	19	15	9	0	2	2	10	0	0	0	6	2
Women's hockey	14	10	17	25	24	27	0	2	7	6	0	0	0	6	7
Women's football	32	4	10	11	4	3	0	1	0	0	0	0	0	0	2
Kayaking	0	1	0	0	0	8	0	1	0	2	1	1	0	0	0
Sailing	4	0	4	2	0	0	0	0	1	0	0	0	0	1	0

In the three team sports, when injuries are collapsed down into the three categories of lower limb, trunk and head and upper limb, the most common injury site is lower limb (Figure 4.5). While for sailing, lower limb injuries constituted 83.33% of all injuries. This was only 10 injuries over the twelve months. By comparison, in women's hockey lower limb injuries made up 65.21%, the equivalent to 90 injuries over the twelve months.

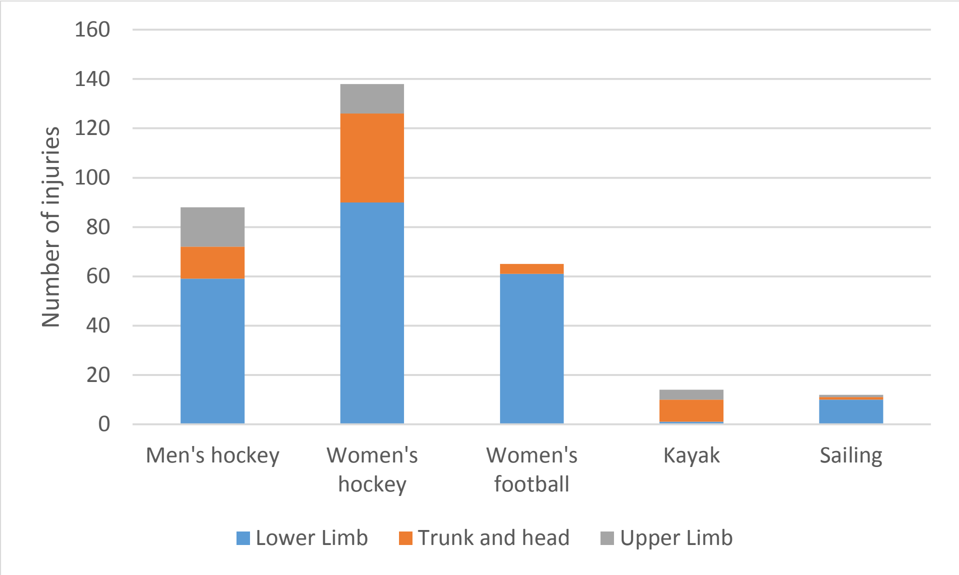

Figure 4.5 Injuries per sport per three body site groupings

Pearson's chi-square test was performed to determine if there was a relationship between the three team sports and the three injury groupings of lower limb, trunk and head and upper limb. In the three team sports, very few athletes sustained upper limb injuries, while lower limb injuries were the most common. There was no statistically significant association between the three sports and either upper or lower limb injuries ($p=0.158$ and $p=0.102$ respectively). Women's hockey athletes sustained significantly more trunk and head injuries than either men's hockey or women's football ($p=0.018$).

4.2.3 Injury Classification

4.2.3.1 Type of Injuries. 245 of the 328 injuries in this study were determined to be acute, 14 were chronic, 35 were reoccurrences and the remaining 34 were unknown. From the data derived from the PILLS app, it was difficult to determine whether any of the injuries were as a result of overuse.

4.2.3.2 Injury Duration. Duration of an injury was determined by how many weeks of missed or modified training resulted from an injury. The average duration of timeloss for an injury for each of the five sports is demonstrated in Table 4.7 with men's hockey, on average, losing more time per injury than the other four sports.

Table 4.7

Average Duration of an Injury

	Average duration of an injury (in weeks)
Men's Hockey	1.57
Women's Hockey	1.14
Women's Football	1.2
Kayak	0
Sailing	0

Figure 4.6 highlights the average length of timeloss per body site with shoulder injuries on average resulting in the greatest amount of time loss from sport, followed by knee injuries. Figure 4.7 then breaks this down further into average time loss per injured body site per sport

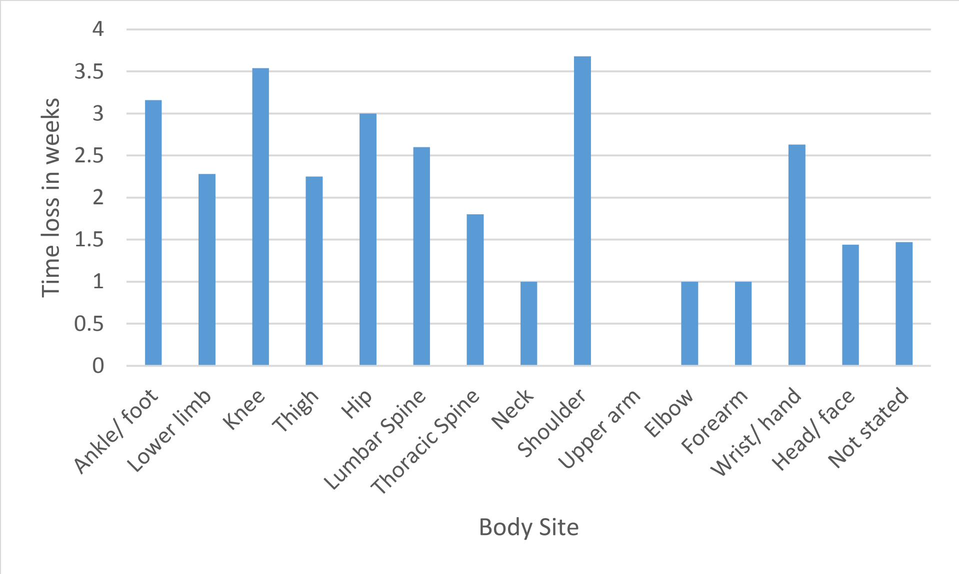

Figure 4.6 Average duration of time-loss injuries per body site across all sports

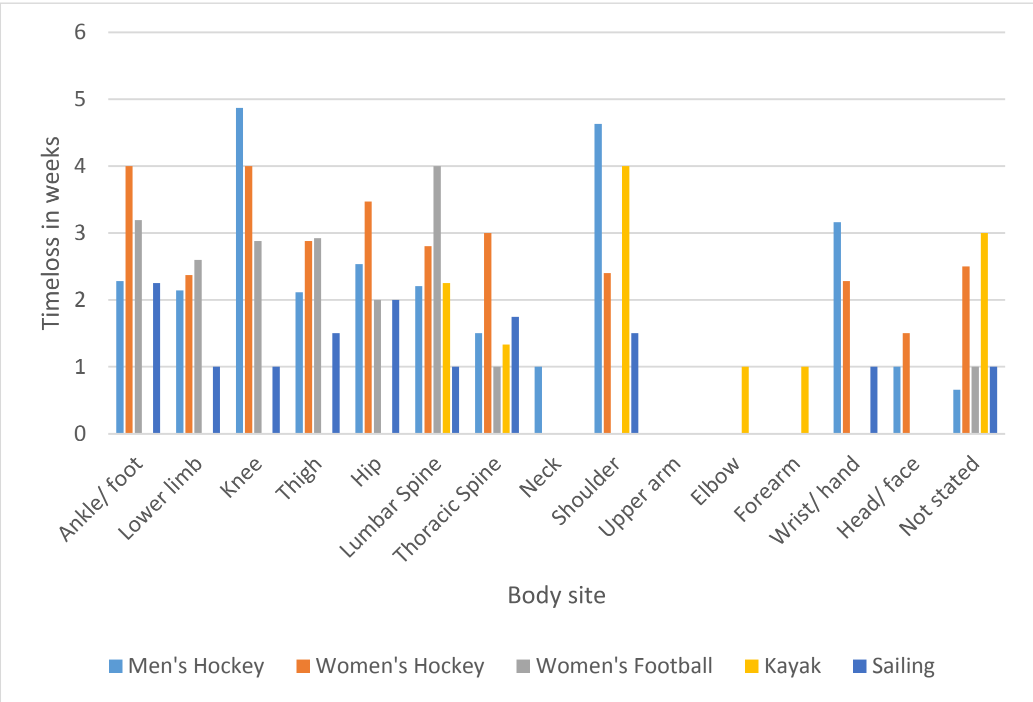

Figure 4.7 Average duration of time-loss injuries per body site per sport

4.2.4. Number of trainings missed/modified due to injury. This study used a time-loss definition for injury, therefore this was monitored through the number of trainings that were either missed or modified. The following tables (Tables 4.8 and 4.9) outline the total number and percentage of trainings that were affected because of injury during this twelve-month study. Table 4.8 outlines the loss to injury across all five sports and then Table 4.9 breaks this down into individual sports. Table 4.9 shows that men's hockey was the sport most affected by time-loss injuries

Table 4.8

Planned trainings and number missed due to injury across all sports

Total reported trainings planned across all 5 sports	Total reported trainings missed/ modified due to injury across all 5 sports	Total reported trainings missed/ modified due to injury as a percentage across all 5 sports
30,090	1654	5.49%

Table 4.9

Planned trainings and number missed due to injury in each sporting code

Sport	Total trainings planned	Total trainings missed/ modified due to injury	Total trainings missed/ modified due to injury as a percentage
Men's hockey	5635	553	9.81
Women's hockey	10,560	744	7.04
Women's football	7549	251	3.32
Kayak	2195	68	3.09
Sailing	4151	38	0.91

4.2.5. Exposure Estimates

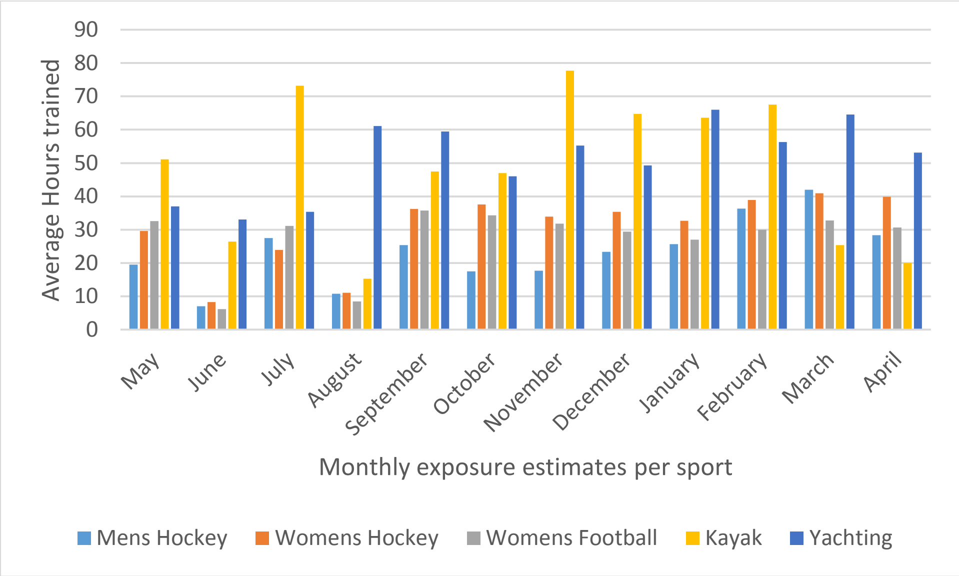

Figure 4.8 Monthly average training exposure estimates per sport

Exposure was determined for the first four sports (men's hockey, women's hockey, women's football and kayaking) by obtaining training time duration estimates and multiplying that by the completed number of training sessions that week. This was then divided by the number of respondents for that sport and the weekly groupings were then totalled together to determine a monthly estimate.

Incomplete training peak data was collected for the nine sailors – so using this, the average weekly training exposure was determined and converted into the twelve monthly groupings. These average exposure estimates are presented in Figure 4.8. The PILLS app did not capture match or competition exposure, so the exposure estimates are for training loads only for the five sports. Figure 4.9 clearly shows that kayaking and sailing have higher average monthly training exposures than the three team sports.

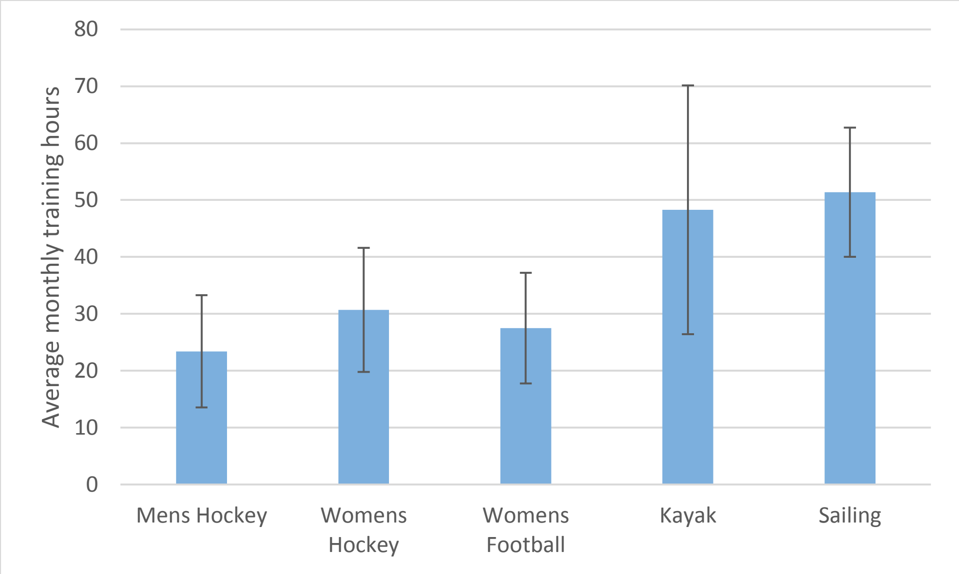

Figure 4.9 Average monthly exposure estimates per sport

4.2.6 Injury incidence and prevalence

4.2.6.1. Injury incidence. Across the five sports combined, 328 time-loss injuries were recorded over the twelve month study period. With a recorded 30,739.4 hours of athlete exposure (AE), the overall injury incidence for all athletes across the five sports was 10.67 injuries/ 1000 AE. Table 4.10 shows the injury incidence per 1000 AE for all five sports with the lowest incidence being in kayak at 4.35 injuries/ 1000 AE, and the highest incidence was found in men's hockey at 14.15 injuries/ 1000 AE.

The data presented is for training injury incidence as the PILLS app only collected information on training exposure.

Table 4.10

Injury incidence per sport

Sport	Number of Injuries	Total exposure hours	Injury Incidence/ 1000 athlete hours
Men's hockey	90	6357.75	14.15
Women's hockey	145	10,836	13.38
Women's football	67	8188.50	8.18
Kayak	14	3214	4.35
Sailing	12	2143.15	5.59

4.2.6.2. Injury prevalence. Overall period injury prevalence across the five sports for the twelve months was 2.79

Table 4.11 shows the period prevalence for the five sports individually with women's hockey having the highest injury prevalence rate at 4.26 compared with kayak which had the lowest at 1.07

Table 4.11

Injury prevalence per sport

Sport	Number of Injuries	Number of athletes	Injury prevalence
Men's hockey	90	33	2.72
Women's hockey	145	34	4.26
Women's football	67	27	2.48
Kayak	14	13	1.07
Sailing	12	9	1.33

4.3 Relationship with load and injury frequency

Figures 4.10 through to 4.14 plot the injury frequency for the five sports against the estimated training exposures for the twelve months of the study. In the sports of hockey and sailing there are progressively greater exposure estimates in the last four months of the year than in the first four months, however, their injury frequencies do not increase. With women's football, the higher exposure loads happen from month four through to month eight of the study, while in kayak the seventh to tenth month had the most load recorded. However, as with the three previous sports, these increased periods of increased exposure do not seem to correlate with an increase in injury frequency. To investigate further, a simple linear regression was calculated to see if injury frequency could be predicted by exposure estimates in the three team sports of men's hockey, women's hockey and women's football, the results of which are outlined in Table 4.12. Because of the small samples in kayak and sailing, a regression model could not be applied to those sports. The linear regression results for the three team sports were nonsignificant which indicates that the associations between increased exposure levels are not predictive of increased injury numbers in this study. The regression findings were as follows:

Table 4.12

Simple Linear Regression findings for the three team sports

	F	**p- value**	**R^2**
Men's hockey	.073	0.793	0.007
Women's hockey	0.786	0.396	-0.020
Women's football	0.095	0.764	-0.90

F = group significance; $p < 0.05$ is significant; R^2 =total variation

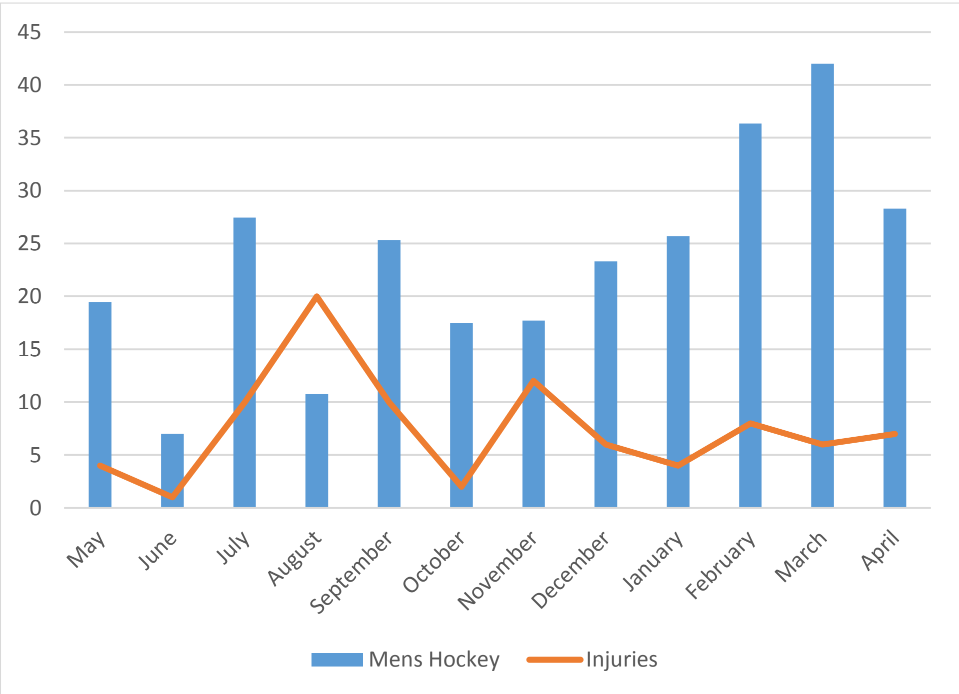

Figure 4.10 Men's hockey training exposure and injury frequency

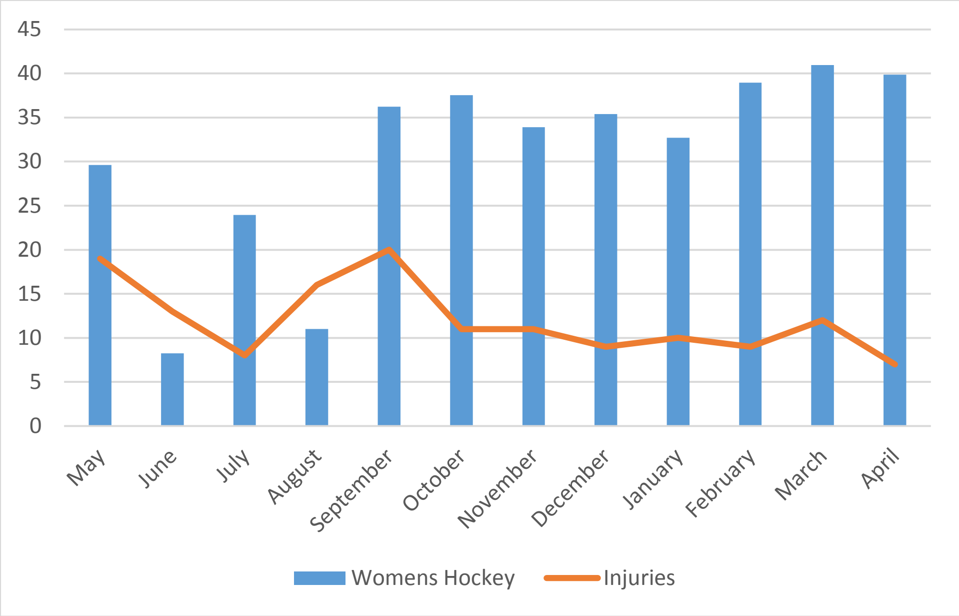

Figure 4.11 Women's hockey training exposure and injury frequency

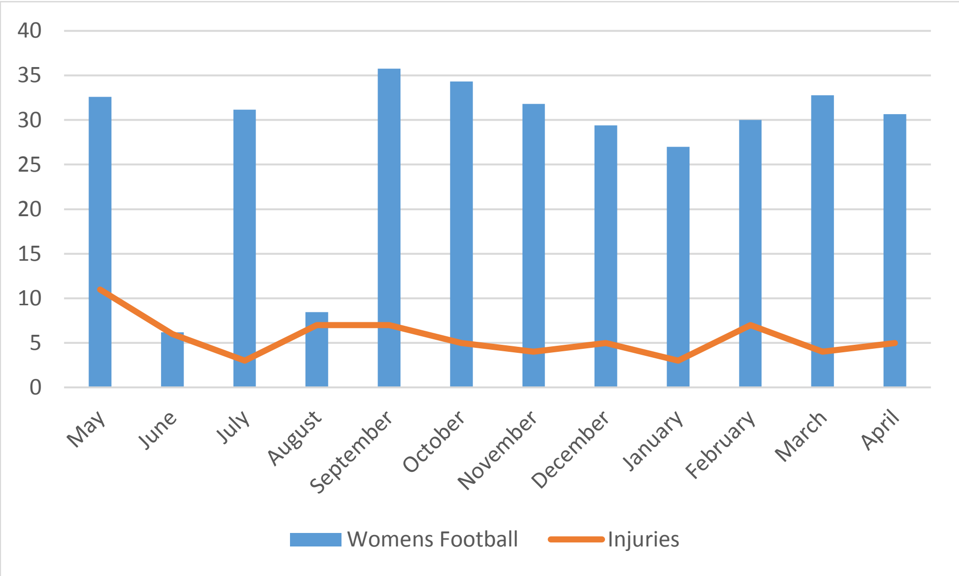

Figure 4.12 Women's football training exposure and injury frequency

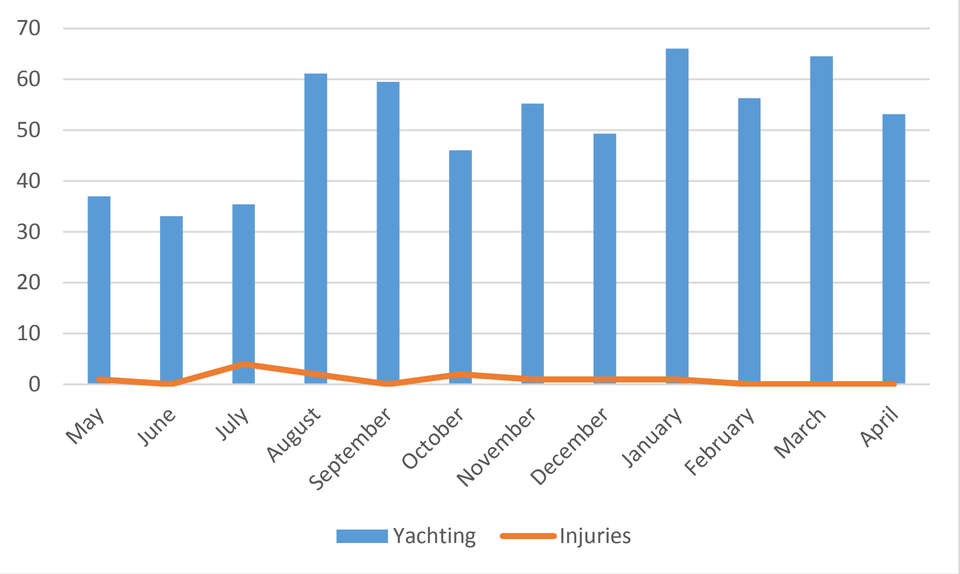

Figure 4.13 Sailing's training exposure and injury frequency

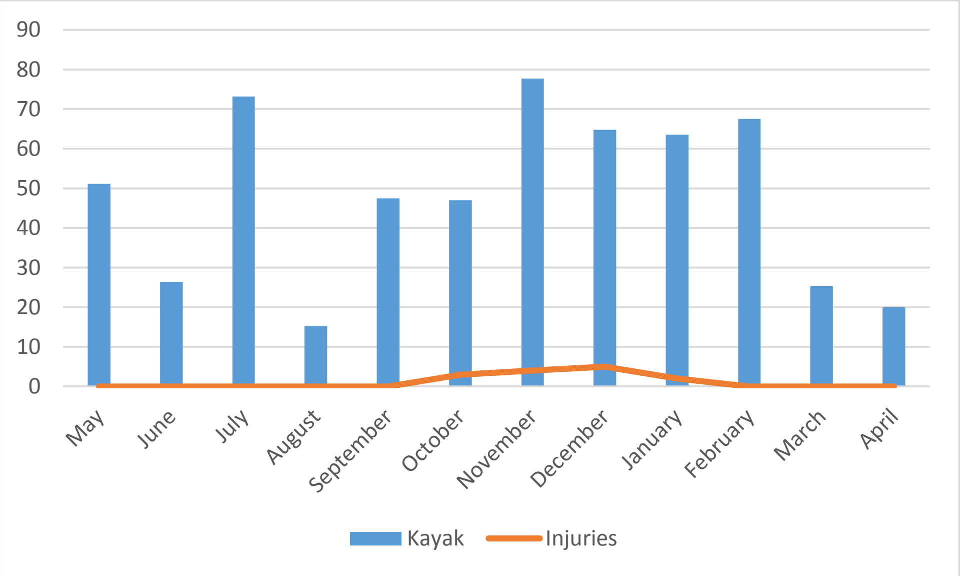

Figure 4.14 Kayak's training exposure and injury frequency

The small sample sizes in both kayak and sailing precluded the use of linear regression to calculate whether exposure estimates could predict injury incidence. In sailing, the highest injury frequency is recorded the month prior to loads increasing. This is the same for kayak with the injury numbers increasing the month prior to the highest exposure levels and then plateauing during the highest month of exposure.

Chapter 5 – Discussion

Introduction

This chapter will review the findings of this study and how they compare to previously published literature. Factors such as compliance, subjects and injuries will be elaborated on and the limitations of this study will be highlighted. Conclusions will then be drawn and suggestions for future research and clinical practice made.

5.1 Subjects

All 115 subjects in this study were New Zealand representative athletes across one of the five following sports; men's hockey, women's hockey, women's football, flat water kayaking and age group sailing. All athletes approached within these NSOs agreed to participate in the study, resulting in a representative sample across these five international disciplines.

From the 115 subjects investigated in this study, 71 were female athletes and 45 were male. The mean age for female athletes was 22.96 years of age and the mean age for male athletes was 24.22 years of age, with no statistically significant difference between the genders.

When the mean ages were looked at across the five sports, the age group sailors had a statistically significant lower mean age at 18.66 years compared with the other four sports which ranged from 23 years through to 25.42 years of age. This was a foreseeable finding as the sailors in this study were the development athletes who tend to be younger than the established elite athletes. Across the entire sample of 116 athletes, the age range was 16-39 years.

This age range is comparable to that investigated by previous studies across the five sports. In hockey, one of the studies had a lowest age of 10 (Sharma et al., 2012) while Murtaugh (2001) and Kelly and Hudson (2010) had lowest ages at 14 and 15 respectively. However, their samples were mixed and did have athletes in their thirties as well. Although the collegiate studies for men's hockey, women's hockey and women's football do not state age range, it can be assumed that the majority are at least 18 years of age due to the regular intake age for college. The lowest reported age in the female football studies was 15 years (Le Gall et al., 2008) however, many female football studies, including all investigating international athletes, did not provide age data (Giza et al., 2005; Dick et al., 2007; Junge & Dvorak, 2007; Tscholl et al., 2007; Rosenbaum et al., 2011; Meyers, 2013; Nilstad et al., 2014).

The main study with a different age range from our sample was in sailing. Hamm and Jee (2016) investigated yacht instructors whose mean age was mid forties. The disparity in age between this study's sailing sample and Hamm and Jee's (2016) reduces the comparability of results between the two studies however, this study was still analysed due to the paucity of sailing literature available.

In this study, the male athletes were significantly taller and heavier than the female athletes ($p<0.001$) on average, measuring in at 11cm taller and weighing in at 11 kilograms heavier. This was expected between the genders and is the same in other epidemiological studies in the elite sporting environment both in New Zealand (Newlands et al., 2015) and internationally (Dick et al. ;2007).

Across the five sports investigated, there were noticeable differences in the athlete samples. Both hockey codes had over 30 athletes each and women's football did not trail too far behind with a sample of 27. These samples are much larger than the 13 kayakers and nine sailors who were investigated. While this did mean that certain statistical analyses were not appropriate for the two smallest samples, it was still important to investigate these populations. With elite sport, the number of athletes participating at the highest level is limited. Within the HPSNZ framework, NSOs have a certain number of athletes who they can support, which is an immediate limitation on sample size. Despite it resulting in low powered studies, baseline data on these athletes remains important to enable the observation of trends within the elite sporting population and plan appropriate injury prevention programmes. Finch et al. (1999) emphasise that it is within the duty of care of a medical team to be collecting injury data on their athletes. There is now 12 months of injury data for these five sports which can then provide a minimum baseline for comparison against future injury surveillance in those sports. This growing database of injuries can then help to provide the foundation of future New Zealand sport-specific injury prevention programmes for those five disciplines.

5.2 Compliance

Overall, this study had a compliance rate of 60.63% across the entire sample. The female athletes in this study had a significantly greater compliance rate than their male counterparts at 72.92% compared with 48.35% ($p<0.01$). In part this may be because there were a greater number of female athletes than male athletes in this study’s sample. Newlands et al. (2015) had a compliance rate in their New Zealand rowing study of 78% so the female compliance rate is equivalent to this, however the male and overall compliance rates in this study are considerably lower than this. This study’s compliance rates are also low in comparison with internationally published studies. Nilstad et al., (2014) had a compliance rate of 69.7% in their injury surveillance study in female football, whereas compliance rates as high as 90-98% (Ekegren, Gabbe & Finch, 2014) and even 100% (Hammond et al., 2014) have been recorded in other studies. Part of the reason for the higher compliance rates may be due to methodology employed. Text messaging was used to collect injury status in the studies by Ekegren et al. (2014) and Nilstad et al. (2014). This was observed to be a convenient method favoured by the athletes, often resulting in instantaneous responses (Ekegren et al., 2014). Hammond et al (2014) achieved their 100% compliance rate by have an investigator present at all trainings and games, therefore recording injuries as they occurred and following up with the athletes as appropriate. While this resulted in perfect compliance, it is a very labour intensive process requiring a lot of resources, and was a method which would not have been achievable in this study.

A contributing factor to the differing compliance rates between the NSOs was how the NSOs promoted PILLS to their respective athletes. Women's football had been used to completing a weekly survey since 2011, so it was second nature to them, whereas men's hockey had not used such a tool before. The use of a new system has previously been identified in epidemiological research as an obstacle to compliance (Ekegren et al., 2014; Finch et al., 1999). Additionally, NSO uptake and promotion of the PILLS app would have influenced athlete compliance. Women's football and women's hockey were very keen to use the new surveillance tool and their management team promoted it very positively to their athletes, a recognised facilitator to compliance (Ekegren et al., 2014). By comparison, the majority of the male flat water kayakers did not have a coach during the course of this study, and as a result did not have any external encouragement to complete the survey, a barrier to compliance (Ekegren et al., 2014).

Additionally, changes in personnel within the NSO's medical teams over the twelve months may have contributed to poor compliance. For example, in flatwater kayak, the physiotherapist duties changed four times over the first six months of the study, a factor which was not anticipated at the beginning of this study. Since new personnel were not involved in the pre-study briefing, they may not have prioritised the collection of data which again, may have contributed to the low compliance rates observed from this NSO. This was also evident in all five NSOs when they went on tour with different medical support staff from those who worked with them domestically. This highlights the need to ensure that all staff involved within an NSO are fully briefed about the importance of injury data collection, to ensure consistent messages and leadership to enhance compliance. While personnel factors have previously been highlighted as a barrier to compliance with injury surveillance (Ekegren et al., 2014), this is not an issue that has been identified in many of the studies reviewed. This largely seems to have been avoided because the prospective studies in hockey and women's football utilised consistent personnel at matches and trainings and provided timely follow up on any injuries sustained rather than relying on athlete reporting (Bowers et al., 2008; Dick et al., 2007; Faude et al., 2005; 2006; Giza et al., 2005; Hartmut et al., 2010; Hendrickson et al., 2008; Mukherjee et al., 2012; Mukherjee, 2013; Tegnander et al., 2008; Thielen et al., 2015). The studies that were reliant on athlete reporting were of retrospective design and tended to use convenience samples and therefore were largely unaffected by compliance issues (Freke & Dalgleish, 1994a; 1994b; Hendrick et al., 2008; Johansson et al., 2016; Kelly & Hudson, 2010; Lovell & Lauder, 2001; Murtaugh, 2001; Naicker et al., 2007; Nathanson et al., 2010; Tan et al., 2016).

The studies undertaken at the Olympic Games relied on medical personnel from each National Olympic Committee to complete injury data on a daily basis. Compliance rates ranged from 73% (Junge et al., 2006) through to 100% (Engebretsen et al., 2013). Reasons why compliance may have been higher in these studies compared with this one is that the Olympic Games on average last about three weeks. Completing injury data for three weeks versus 52 weeks is less demanding and all the physicians were briefed on the importance of providing injury data at the start of competition (Junge et al., 2006).

This study's figures would have been different if a threshold of questionnaire completion had been set. If this was not met, those non-compliant athletes would have been removed from the sample, similar to Newlands et al. (2015). However, it was a deliberate decision not to do this so that the impact of non-compliance on the injury data collected could be assessed.

5.3 Injuries

Consistent with previously published literature, the three team sports in this study had much higher injury numbers than both kayak and sailing (Engebretsen et al., 2013; Junge et al., 2009). Previous literature also found that male hockey players experience a higher injury incidence than female hockey players (Junge et al., 2004; Thielen et al., 2015). This was not the case in this study, with women's hockey having the highest injury incidence of any sport, but this may be a misleading finding. Despite the second lowest compliance rate of this study at 48.15%, men's hockey reported the second highest injury total of 90 injuries over twelve months, an average of 2.72 injuries per athlete. It suggests that the impact of injuries on men's hockey may be dramatically greater than identified in this study, however the aforementioned compliance issues prevent us from being able to identify this. Conversely, there is an argument that compliance levels may increase when an athlete is injured as the injury acts as a "reminder" to the athlete to complete their PILLS app however, anecdotally, this was not a trend noticed within this study.

5.3.1 Injury site. The most common injury sites in each sport were as follows: Men's hockey was the thigh, women's hockey was lower back, women's football was ankle injuries which made up just over 47% of all their injuries, kayak was lower back and sailing was jointly ankle and foot injuries and knee injuries. Previous hockey research has suggested that the lower limb is the most commonly injured site (Junge et al., 2004; Murtaugh, 2001;

Sharma et al., 2012). When this study's data for hockey was collapsed into three groupings for body sites injured (upper limb, lower back and lower limb) then this was also true for both men's and women's hockey.

This is the same conclusion for women's football, with lower limb injuries making up 61 of the reported 67 injuries in this study. This supports the findings in previous studies where the lower limb has been the significant area of the body injured (Dick et al., 2007; Jacobson & Tegner, 2007; Junge & Dvorak, 2007; Le Gall et al., 2008). Specifically, ankle injuries were also found to be the most common injury sustained in female football by two papers (Dick et al., 2007; Junge & Dvorak, 2007). This study's findings are consistent with these papers. The high speed running demands coupled with frequent changes of direction in both hockey and football inevitably contribute to the high volume of lower limb injuries.

Kayaking sustained most of their injuries to the lower back with eight out of the 14 injuries being recorded at that site compared with only four upper limb injuries. Previous studies have reported a predominance for upper limb injuries in kayak, however, of the five studies reviewed, two did not mention the body site injured (Engebretsen et al., 2013; Junge et al., 2009) and two focused primarily on upper limb injuries (Johansson et al., 2016; Piasecki et al., 2008). Therefore, these four papers are likely not representative of the nature of injuries in elite kayaking. By comparison, Lovell and Lauder (2011) divided injuries into upper limb and trunk injuries, suggestive that the trunk is an important injury site for kayakers (Lovell & Lauder, 2001). Kayak has been identified as a sport with a low injury risk which may partially explain why there is so little published literature regarding its injury incidence (Engebretsen et al., 2013; Junge et al., 2009). This study saw the worst compliance rate from the kayak NSO at 25.60%, suggesting that the true extent of injury incidence in the sport of kayaking may not have been captured by this research. Additionally, due to the high training exposures and repetitive nature of the discipline, kayak is much more likely to be impacted by overuse injuries, rather than acutely traumatic issues. These overuse injuries may not immediately result in time loss from training and therefore would not have been captured in this study.

Sailing athletes sustained an equal number of injuries to ankles, feet and knees accounting for 66% of all of their injuries in this study. This corroborates findings from previous literature where the lower extremity was found to be the most commonly injured site (Bøymo-Having et al., 2013; Ham & Jee, 2016; Nathanson et al., 2010). This is an interesting finding, given the large amount of upper body work that occurs during sailing. There is a possibility that off-water training focuses more on upper body conditioning rather than lower limb, but further research would be required to determine a) if that is correct and b) if that then influences injury patterns observed in sailors.

5.3.2 Injury duration. This was captured using the number of training weeks lost as a result of injury, with over six weeks of missed or modified trainings being classified as severe. This differs from other studies for example, Junge and Dvorak (2000) classified all injuries that caused problems to an athlete for four weeks or more, or that resulted in timeloss of three weeks or more from football as severe injuries in their study.

Because of the weekly design of the PILLS app, injury duration was only able to be captured in this study by the number of weeks that an athlete reported missed or modified trainings. While Junge and Dvorak (2000) utilised weekly measures, this has been replaced by recent literature advocating the measure of injury severity by number of days missed (Fuller et al., 2006; 2007). This is why this study used the term injury duration rather than severity. While this may have resulted in an overestimation of the duration of time that injuries took to recover because a week where one training was modified was still classed as an “injury-impaired” week, it was the most reliable method the primary researcher could employ.

It is also unusual for an athlete to not have any training to complete when injured. While these sessions should be classified as “modified”, for example an upper body only gym programme for someone with a hamstring strain, it is suspected that the accuracy of athlete reporting for this was not always 100%. It is hoped, therefore, that the overestimation error and underestimation error in this study will balance each other out.

Therefore, to try to ensure less catastrophic figures, our injury duration was considered to be mild if only for one week, moderate if two to six weeks and severe if six weeks or more were lost from training. This does reduce the comparability of these results with other studies.

5.3.3 Injury type. To determine whether an injury was a new injury, the PILLS app relied on the date of injury question being completed. While this enabled the primary researcher (JS) to determine if it was a new injury, there was no option for enlarging on whether the injury was an exacerbation or recurrence or how it had happened. This unfortunately was a limitation of the PILLS app which prevented the SIC model from being applied to our data (Finch & Cook, 2014). Another limitation of the PILLS app was that it was impossible to determine if an injury was traumatic or as a result of overuse, so it is suspected that the true extent of overuse versus traumatic injuries was overlooked in this study. This lack of information has implications for the quality of baseline injury surveillance data being collected by HPSNZ. Nevertheless, the PILLS app was designed to be a “clinical tool” and, as such, does allow us to comment on which body site has been injured. Detail surrounding injury type is limited from the PILLS app and has to be captured through other facets of the PILLS employed by HPSNZ.

5.3.4 Injuries that resulted in greatest timeloss. The injuries that resulted in the greatest time lost from sports did not correspond with the body site most commonly injured in the five sports, apart from sailing. In men's hockey, shoulder injuries resulted in an average of four and a half weeks lost from training, knee and ankle injuries cost women's hockey on average four weeks, low back injuries cost women's football four weeks and shoulder injuries cost kayak four weeks.

Women's hockey and kayak's results appear to correspond with previous international literature for these sports with both lower limb and upper limb being identified as commonly injured areas in both sports (Junge et al., 2004; Murtaugh, 2001; Johansson et al., 2016; Piasecki et al., 2008). However, a high incidence of shoulder injuries in men's hockey and lower back injuries in women's football are not previously mentioned in the published literature. Further investigation of these figures shows that particular injuries have impacted these results. Men's hockey sustained ten shoulder injuries over twelve months, the majority of which lasted the duration of two weeks, however two of these injuries were of severe duration. One resulted in eight weeks' time loss following a conservative management programme. The second severe shoulder injury was another dislocation which was managed surgically resulting in 16 weeks of missed/ modified trainings. These two injuries influenced the mean injury duration for shoulder injuries in men's hockey. In women's football, one lower back injury affected the mean injury duration for the three low back injuries. This episode of low back pain occurred prior to the 2015 FIFA Women's World Cup and resulted in ten weeks of missed or modified trainings. The other two injuries to lower backs were only recorded for one week each. This highlights how important it is to be able to extrapolate further data from the other sources of the PILLS.

5.3.5 Injury incidence. Over twelve months the overall injury incidence across the five sports combined was 10.67/1000 training AEs. When broken down into specific sports, the training injury incidence were 14.15/1000 AEs for men's hockey, 13.38/1000 AEs for women's hockey, 8.18/1000 AEs for women's football, 4.35/1000 AEs for kayaking and 5.59/1000 AEs for sailing. The injury incidences for the three team sports were similar to previously published studies whereas minimal literature was identified that reported injury incidence for flatwater kayaking or for sailing. The injury incidences for the three team sports were vastly greater than those noted in sailing and kayaking as supported by previous literature (Engebretsen et al., 2013; Junge et al., 2009).

To this author's knowledge, this is the first study to detail injury incidence for flatwater kayaking as none of the studies identified in the literature review commented or reported on this. The low injury incidence does correspond with the finding from the Olympic Games' studies which reported kayaking to be in the five sports where athletes were most unlikely to get injured during competition (Engebretsen et al., 2013; Junge et al., 2009).

The only study in sailing that reported injury incidence was Tan et al. (2016) who reported an in-tournament injury incidence of 0.59 injuries/ 1000 sailing hours. This is considerably less than the 5.59 injuries/ 1000 AE observed in this study. However, this study also collects information from off water training such as gym work. Tan et al. (2016) also noted that overuse injuries are the most common form of injuries in sailing, and whether they would be captured in their prospective injury surveillance during the World Championships is unknown. That may explain why the injury incidence for the sailors in this study is higher as over the course of twelve months, an athlete is more likely to present with an overuse complaint than they are in a competition spanning five days. Nevertheless, if an overuse injury did not result in time lost from training, it would not have been captured in this study.

5.3.6 Injury prevalence. This study found women's hockey to have the highest injury prevalence out of the five sports. This corresponds to the baseline OSTRC results at the start of the study which demonstrated that 20 from the cohort of 34 women hockey players declared an injury status prior to the study beginning, which was by far the greatest percentage of the five sports. Women's football also had a slightly greater number of athletes declaring injury on their OSTRC forms than those who did not, however during the study their injury prevalence was much lower than hockey's at 2.48 compared with 4.26.

Interestingly, kayak also had just over fifty percent of their athletes report injury at baseline on the OSTRC. This trend did not persist in the subsequent twelve months, but highlights the difference between what data the OSTRC captures compared with the PILLS app. The OSTRC has the capability to capture all kinds of injury data, including overuse issues as well as acute injuries (Clarsen et al., 2014) so can identify issues even if they do not result in time loss from a sport. The PILLS app is only concerned with timeloss injury data, meaning that many complaints will not have been captured. It could be reasoned that with their high exposure loads and repetitive non-contact nature of the discipline, kayakers would be more susceptible to overuse injuries than acute traumatic ones. This may explain why baseline OSTRC injury measures in kayak are greater than those recorded by the PILLS app as the two tools have different purposes, and collect data on different types of injuries. This could be an area for further investigation by the kayak NSO. Unfortunately, there were no other published studies that looked at this type of injury data for kayaking, therefore it is unknown whether this is a normal finding within the elite kayaking population.

5.4 Exposure

The PILLS app collected the number of planned, missed and modified trainings for the week, but no time measure was assigned to training. Therefore, in order to be able to provide an estimate, average training times were used directly from the strength and conditioning staff aligned with each NSO. These strength and conditioners are present at a number of the week's sessions, so while the exposure captured is estimated, it is as accurate an estimate as we could make. It does not take into account if a training session over-runs, or any individual athlete training restrictions.

Ideally, load measures would be collected from each individual athlete on a daily basis for each training session that they completed. Additionally, any modifications would be recorded in "real time" and therefore reduce any recall bias. These load measures, coupled with perceived exertion scores would then provide more meaningful data and more accurate exposures for each individual athlete, rather than using an average for each athlete.

Additionally, training and match/ competition exposures need to be collected across all sports to enable the calculation of precise exposure-related incidence (Junge & Dvorak, 2000). This is something which this study was unable to achieve. Ideally, future study would include injury incidence for trainings, injury incidence for games/ competition and overall injury incidence measures based on individualised exposure measures (Fuller et al., 2006; Junge & Dvorak, 2000).

5.5 Relationship between exposure and injury numbers

This study found that estimated exposures in the five sports under investigation did not predict injury trends. This contradicts findings in a previous study in New Zealand rowers where increased training loads resulted in increased injury incidence (Newlands et al., 2015).

As mentioned in the previous section, the estimation of the exposures used in this study will have compromised the reliability of the measure, and this may have contributed to the nonsignificant results. Additionally, the relatively small sample sizes in all five sports, particularly in sailing and kayaking may also have reduced the significance of any trend. While the sample sizes cannot be altered, the recording of daily individualised exposure measures may result in the trends seen in this study becoming significant results with exposure being a significant predictor of injury.

5.6 Limitations

The small sample sizes across the five sports, particularly in sailing and kayak, limited the amount of statistical analyses that were able to be undertaken and reduced the external validity of these results. Nevertheless, findings in elite sporting populations are not always comparable to non-elite level (Bøymo-Having et al., 2013). It is also a limited population by the fact that it is elite in nature. It is therefore hard to increase the sample size when only a finite amount of athletes compete at the elite level in any country. Possible ways that the sample sizes could be expanded would be to also include age group/ development athletes in the investigation but, as previously mentioned, their injury profiles can significantly differ from those of elite athletes. In this study, sailing's sample could be increased by the inclusion of the twelve elite athletes who did not participate. If sample sizes cannot be increased, then an emphasis on increased quality of data would be the way to progress this study, so providing greater injury data and detail to add more to the existing knowledge base around each sport.

The capturing of exposure measures through the PILLS app alone is insufficient to determine an individual athlete's exposure accurately. There is also wide variety between each NSO on how exposure measures are collected outside of the PILLS app. Therefore, it is recommended that NSOs work in conjunction with HPSNZ to determine more effective and consistent measures to record daily exposures for each athlete, regardless of what discipline they compete in. Even in sailing, where an additional programme was used, the incomplete data sets resulted in estimates having to be used. The average training exposure estimates were then applied to each sailor, regardless of which Olympic class they competed in. Again, this decreases the accuracy of this study's results as training exposures will vary dependent on athlete's individual needs and the type of boat they are in.

The PILLS app was developed as a tool to be used in conjunction with NSO specific injury surveillance. As such, the app captures only a limited amount of data regarding injuries. A limitation of this study is that the additional data collected on injuries was not analysed in addition to the PILLS app data. If it had been, greater information regarding injuries sustained and a clearer picture of the injury impact on a sport would likely have been determined. It is also a way to determine in more detail the problem of compliance. OSICs codes from treatments undertaken in the HPSNZ clinic could then be compared with weekly survey results to ascertain;

i) The reliability of what injury is reported by the athlete compared with what is seen by the therapist.

ii) Whether PILLS app compliance is improved or decreased in the presence of an injury.

Cross referencing the data collected by the PILLS app in tandem with other sources such as OSICS codes and clinic notes would then provide further detail about injuries. This could include, but not be limited to, injury mechanism, injury classification (ie. exacerbation or index injury) and detail regarding its origin as either traumatic or overuse. This additional detail would provide higher quality injury data and enable the application of recognised injury classification systems to be used (Finch & Cook, 2014; Meeuwisse et al., 2007).

This will then help in the development of a truly detailed and accurate database of baseline injury issues for each sport within the HPSNZ umbrella (Finch & Cook, 2014).

The greatest limitations of this study, are those which affect all injury surveillance methodologies reliant on self-reporting systems. Accurate reporting and recall are required to provide accurate data, and when this does not occur, the data is susceptible to bias. In this study, reporting inconsistencies were noted from some athletes who were having treatment and on modified training loads, yet they would deny the presence of injury on the PILLS app. This was attributed to it taking more time to detail an injury on the PILLS app rather than deny the presence of one. Compliance is paramount to establish quality injury data, not only at an individual athlete level but also from an NSO level. The NSOs who actively encouraged the use of the PILLS app as part of their injury surveillance had much better compliancy than the other NSOs. Without the active engagement of coaching and management, the compliance levels were low, undermining the quality of the injury data collected.

5.7 Conclusion

This study's purpose was to determine injury incidence and prevalence across the five HPSNZ sports of men's hockey, women's hockey, women's football, kayaking and sailing using the HPSNZ injury surveillance tool (the PILLS app). Training injury incidence was 14.15/1000 AEs for men's hockey, 13.38/1000 AEs for women's hockey, 8.18/1000 AEs for women's football, 4.35/1000 AEs for kayaking and 5.59/1000 AEs for sailing. Injury prevalence was 2.72 for men's hockey, 4.26 for women's hockey, 2.48 for women's football, 1.07 for kayaking and 1.33 for sailing. The PILLS app did not collect data on match/ competition exposure, therefore this study was unable to determine match/ competition injury incidence for the five sports under investigation.

Although an increase in exposure loads was not predictive for increased injury rates in this study, which differs from previous publications, this may be due to how exposure was collected. It was found that the PILLS app alone did not capture exposure adequately, looking only at training exposure and not providing any unit of measurement for this. This meant that generic estimates had to be employed for each sport. It was therefore concluded that the

PILLS app was deficient in some areas of injury surveillance. Compliance was the biggest barrier to the PILLS app and the enthusiasm with which this system was adopted by the NSOs seems to have predicted how compliant the sport would be with this system.

5.8 Future Research

The results of this study showed that the data from the PILLS app would be more complete if used in conjunction with other injury surveillance methods employed simultaneously within HPSNZ. It would then help to negate the limitations that come from data that is solely self-reported, as well as the limitations of the PILLS app itself.

Additionally, how athlete exposure is collected within HPSNZ needs to be evaluated to ensure measures are timely, accurate and individualised to each HPSNZ athlete. They need to reflect both the training and competition environment in which the athletes participate. The most complete exposure data in the reviewed literature occurred when management i.e. coaches or trainers, recorded athletes' exposure. A study comparing athlete self-reported exposure with management recorded exposure, may help to highlight any discrepancies between the two methods and help to frame future practice at HPSNZ. Closer collaboration between medical, coaching and strength and conditioning staff within NSOs could ensure that all athlete exposure is collected on an individual basis from all training sessions, providing a detailed and accurate exposure profile for all athletes.

Future studies could look at overuse injuries within these five sports. While these injuries may not result in time lost from the sport, they could still be impacting on the athletes' performance and their impact was not investigated within the scope of this study.

The biggest barrier to this study was compliance, so future investigation into the barriers within an HPSNZ environment that reduce compliance may be worthwhile. These findings could then be taken into account if and when new systems are introduced.

5.9 Clinical Relevance

The results of this study provide a baseline indicator of the injury issues facing the five sports of men's hockey, women's hockey, women's football, kayaking and sailing. They can also begin to direct the injury prevention programmes for these sports. For example, the three team sports experienced large numbers of lower limb injuries, therefore, lower limb strength, stability, proprioception and motor control should be priorities addressed within injury prevention programmes for those sports.

Injury prevention programmes need to have significant impact on the injury picture facing NSOs. This research can help to prioritise what is targeted in specific sports' injury prevention programmes. A good example of how this research can help with this is in women's football. 47.76% of all injuries sustained in women's football were to the foot and ankle, therefore this should be a priority area addressed in any injury prevention programme undertaken by that NSO.

The difference in injury patterns between men's and women's hockey identifies the need for tailored injury prevention programmes for the two codes. While both hockey codes experienced a lot of lower limb injuries, women's hockey had considerably more lower back injuries than the men. This may identify an area in the women's programme which needs addressing, for example, if the strength and conditioning programmes are not adequately addressing the female athletes' core strength. However, it may be that the two hockey codes are comparable in their conditioning programmes and therefore, the results may suggest that female hockey players are more vulnerable to lower back injuries than their male counterparts. This has not been reported in any previous research, so may be an area that warrants future investigation by the NSO.

The small samples in both kayak and sailing, coupled with the low compliance rates, make it hard to influence clinical practice based on this study's results. What this study does endorse is that any clinician working in either of these sports should be encouraged to collect and publish their injury data to contribute to the body of information available regarding the injury challenges faced by both of these sports.

This study also recognises the importance of having a well-developed injury surveillance tool with which to collect information. Injury surveillance is a time consuming, yet necessary part of clinical practice within elite sporting environments. It is therefore imperative that tools used to assist data collection are capable of producing complete data sets pertaining to injury. This includes exposure measures for both training and competition, details regarding the nature of the injury and they must be simple to encourage athlete compliance.

This study identified compliance as the greatest challenge to injury surveillance. When implementing injury surveillance within a sporting environment, practitioners should ensure that all parties involved understand the importance of the data collection and why the results are important. It is suggested that regular feedback to the involved parties may increase understanding and interest in the process, resulting in greater compliance and then more accurate injury baselines for sport will be established. These baselines can then be used to direct appropriate injury prevention programmes.

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Appendix A HPSNZ PILLS app questions

Manual Entry Sheet for PILLS Survey		ENTER INFORMATION IN THIS COLUMN
Surveyed Date	6/02/17	When question is shaded grey or blue choose only 1 option
Q2. How many training sessions did you have planned?		
Q3. How hard would you rate your training? Easy	Easy	
Q3. How hard would you rate your training? Moderate	Moderate	
Q3. How hard would you rate your training? Hard	Hard	
Q3. How hard would you rate your training? Very Hard	Very Hard	
Q4. In training did you TRAIN FULLY ALL SESSIONS? Yes	Yes	
Q4. In training did you TRAIN FULLY ALL SESSIONS? No	No	
Q5. How many training sessions did you MISS or MODIFY due to factors OTHER THAN INJURY or ILLNESS?		
Q6. Did you miss and/or modify any training sessions due to INJURY? Yes	Yes	
Q6. Did you miss and/or modify any training sessions due to INJURY? No	No	
Q7. How many did you MISS due to Injury?		
Q8. How many did you MODIFY due to Injury?		
Q9. WHEN did the injury occur?		
Q10. WHERE did the injury occur? Sport	Sport Specific Training	
Q10. WHERE did the injury occur? Gym	Gym Based Training	
Q10. WHERE did the injury occur? Competition	Competition	
Q10. WHERE did the injury occur? Somewhere Else	Somewhere else	
Q11. WHAT did you injure?Head/Face	Head/Face	
Q11. WHAT did you injure?Neck/Trunk	Neck/Trunk	
Q11. WHAT did you injure?Lower Back	Lower Back	
Q11. WHAT did you injure?Shoulder	Shoulder	
Q11. WHAT did you injure?Arm	Arm	
Q11. WHAT did you injure?Wrist/Hand	Wrist/Hand	

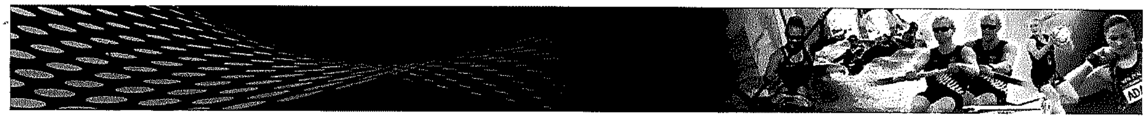
Q11. WHAT did you injure?Hip/Groin	Hip/Groin	
Q11. WHAT did you injure?Thigh	Thigh	
Q11. WHAT did you injure?Knee	Knee	
Q11. WHAT did you injure?Lower Leg	Lower Leg	
Q11. WHAT did you injure?Ankle/Foot	Ankle/Foot	
Q12. Severity of your INJURY symptoms TODAY. 1	1 (Minimal)	
Q12. Severity of your INJURY symptoms TODAY. 2	2	
Q12. Severity of your INJURY symptoms TODAY. 3	3	
Q12. Severity of your INJURY symptoms TODAY. 4	4	
Q12. Severity of your INJURY symptoms TODAY. 5	5	
Q12. Severity of your INJURY symptoms TODAY. 6	6	
Q12. Severity of your INJURY symptoms TODAY. 7	7	
Q12. Severity of your INJURY symptoms TODAY. 8	8	
Q12. Severity of your INJURY symptoms TODAY. 9	9	
Q12. Severity of your INJURY symptoms TODAY. 10	(Severe) 10	
Q13. Which side did you injure? Left	Left	
Q13. Which side did you injure? Right	Right	
Q13. Which side did you injure? Both	Both	
Q13. Which side did you injure? NA	Not applicable	
Q14. What type of injury do you have?Bone injury	Bone injury	
Muscle injury	Muscle injury	
Tendon injury	Tendon injury	
Joint injury	Joint injury	
Skin wound	Skin wound	
Concussion	Concussion	
Post-operative	Post-operative	
Other	Other	
Don't know	Don't know	
Q15. Do you have a diagnosis of your INJURY? No	No	
Q15. Do you have a diagnosis of your INJURY? Define	Yes - please define	
Q16. Do you have any other injuries impacting on your training or performance? No	No	

Q16. Do you have any other injuries impacting on your training or performance? Yes	Yes - please define	
Q17. Did you miss or modify training sessions due to ILLNESS? Yes	Yes	
Q17. Did you miss or modify training sessions due to ILLNESS? No	No	
Q18. How many did you MISS due to Illness?		
Q19. How many did you MODIFY due to illness?		
Q20. Please indicate the affected area/systems. Head/Throat	Head/Throat	
Q20. Please indicate the affected area/systems. Chest/Heart	Chest/Heart	
Q20. Please indicate the affected area/systems. Gut	Gut	
Q20. Please indicate the affected area/systems. Skin	Skin	
Q20. Please indicate the affected area/systems. Fatigue	Fatigue	
Q20. Please indicate the affected area/systems. Other	Other	
Q21. Do you have an infection? Yes	Yes	
Q21. Do you have an infection? No	No	
Q22. Please rate the severity of your ILLNESS symptoms TODAY. 1	1 (Minimal)	
Q22. Please rate the severity of your ILLNESS symptoms TODAY. 2	2	
Q22. Please rate the severity of your ILLNESS symptoms TODAY. 3	3	
Q22. Please rate the severity of your ILLNESS symptoms TODAY. 4	4	
Q22. Please rate the severity of your ILLNESS symptoms TODAY. 5	5	
Q22. Please rate the severity of your ILLNESS symptoms TODAY. 6	6	
Q22. Please rate the severity of your ILLNESS symptoms TODAY. 7	7	
Q22. Please rate the severity of your ILLNESS symptoms TODAY. 8	8	
Q22. Please rate the severity of your ILLNESS symptoms TODAY. 9	9	
Q22. Please rate the severity of your ILLNESS symptoms TODAY. 10	(Severe) 10	
Q23. Do you have a diagnosis? No	No	

Q23. Do you have a diagnosis? Yes	Yes - please define	
Q24. Do you have any other illnesses impacting on your training or performance? No	No	
Q24. Do you have any other illnesses impacting on your training or performance? Yes	Yes - please define	
Q25. In the last 7 days did you consult a PHYSIOTHERAPIST? No	No	
Q25. In the last 7 days did you consult a PHYSIOTHERAPIST? Yes	Yes - enter number of appointments	
Q26. In the last 7 days did you consult a DOCTOR? No	No	
Q26. In the last 7 days did you consult a DOCTOR? Yes	Yes - enter number of appointments	
Q27. In the last 7 days did you consult a MASSAGE THERAPIST? No	No	
Q27. In the last 7 days did you consult a MASSAGE THERAPIST? Yes	Yes - enter number of appointments	
Q28. In the last 7 days did you consult another HEALTH PROFESSIONAL? No	No	
Q28. In the last 7 days did you consult another HEALTH PROFESSIONAL? Yes	Yes - What type of Health Professional?	
Q29. In the last 7 days have you had investigations-X-ray	X-ray	
Q29. In the last 7 days have you had investigations-CT Scan	CT Scan	
Q29. In the last 7 days have you had investigations-Ultrasound Scan	Ultrasound Scan	
Q29. In the last 7 days have you had investigations-MRI Scan	MRI Scan	
Q29. In the last 7 days have you had investigations-Blood tests	Blood tests	
Q29. In the last 7 days have you had investigations-Other	Other	
Q29. In the last 7 days have you had investigations-None	None of the above	
Q30. How ready are you today to train or compete at your best?	0%	
Q30. How ready are you today to train or compete at your best? 10%	10%	
Q30. How ready are you today to train or compete at your best? 20%	20%	
nQ30. How ready are you today to train or compete at your best? 30%	30%	

Q30. How ready are you today to train or compete at your best? 40$	**40$**	
Q30. How ready are you today to train or compete at your best? 50%	**50%**	
Q30. How ready are you today to train or compete at your best? 60%	**60%**	
Q30. How ready are you today to train or compete at your best? 70%	**70%**	
Q30. How ready are you today to train or compete at your best? 80%	**80%**	
Q30. How ready are you today to train or compete at your best? 90%	**90%**	
Q30. How ready are you today to train or compete at your best? 100%	**100%**	
Q31. Do you wish to speak with Medical Staff? No	**No**	
Q31. Do you wish to speak with Medical Staff? Yes	**Yes - please indicate whether Doctor or Physio.**	

Appendix B PILLS consent form



Programme for Injury and Illness Surveillance (PILLS) Consent Form

Athlete consent for the collection, use and storage of Programme for Injury and Illness Surveillance (PILLS) information/data

Introduction

The primary goal of PILLS is to ensure that your sports Medical Director and medical team have up to date information on your injury and illness status. This regular data will support timely interventions from the medical team. In addition, over time, the data will mean that a personalised injury and illness profile can be developed for you, helping you to have optimal preparation for pinnacle events.

This consent form is an extension of the current *"HPSNZ Consent to the Collection and Storage of Personal Information Consent"* Form, which all carded athletes are required to sign. This new form gives consent for HPSNZ and the people that constitute the organisation, to access your PILLS data that is de-identified or aggregated (ie. no-one will be able to tell it is you) for research that aims to develop injury profiles and that will ultimately optimise health and performance of athletes in NZ.

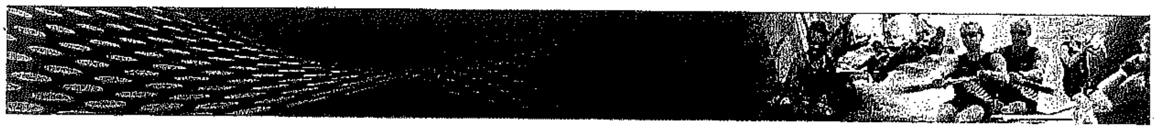
By signing this consent form

I understand and agree that the organisation and people that constitute HPSNZ (as outlined in the HPSNZ Collection and Use of Athlete Information Brief), will only collect, store, analyse, present and/or disclose my individual PILLS information to members of the HPSNZ and respective NSO Medical Teams, for the purposes of enhancing support services provided to me as a carded athlete.

I understand and agree that HPSNZ and the people that constitute the organisation may utilise my PILLS data for research purposes and improving HPSNZ sports medicine services whilst I am a carded athlete and for a following period of ten years. This includes the presentation of anonymised and grouped data in publications and presentations. Data used for research purposes will be de-identified and aggregated. Personal details such as name will not be used and I will be identified by a unique research number only.

I understand that in collecting, using, storing and/or disclosing my personal information HPSNZ and all contracted service providers and other authorised individual will at all times comply with the Privacy Act 1993 and the Health and Disability Commissioner Code of Health and Disability Services Consumers' Rights Regulation 1996.

I understand that this Consent form is an extension to the Current HPSNZ Consent to the Collection and Storage of Personal Information Consent Form and relates specifically to PILLS and the release of my PILLS data for research purposes.



I understand and agree that in signing this consent I am authorising the disclosure of my PILLs data and information to relevant individuals within my National Sporting Organisation (NSO).

I understand that I have the right of access to, and the right to amend any of my PILLs information that HPSNZ retains in its possession.

I understand that I can refuse to sign this consent form for the utilisation of my de-identified data for research purposes without any adverse consequences.

I also confirm that:

a) I have been provided with a copy of the PILLS Athlete Information Sheet.
b) I have had the opportunity to seek independent advice about my right to privacy and my right to refuse to give consent to the disclosure of any information collected by the HPSNZ PILLS survey.
c) I may withdraw this consent with respect to research purposes at any time.

Athlete Authorisation

SIGNATURE: ______________________ DATE: ________

NAME: ______________________

(Please Print)

Witnessed by

SIGNATURE: ______________________ DATE: ________

NAME: ______________________

(Please Print)

Appendix C Modified OSTRC Baseline Questionnaire

Question 1

Have you had any difficulties participating in normal training and competition due to injury during the past week?

☐ Full participation without injury

☐ Full participation, but with injury

☐ Reduced participation due to injury

☐ Cannot participate due to injury

Question 2

To what extent have you reduced your training volume due to injury during the past week?

☐ No reduction

☐ To a minor extent

☐ To a moderate extent

☐ To a major extent

☐ Cannot participate at all

Question 3

To what extent has injury affected your performance during the past week?

☐ No effect

☐ To a minor extent

☐ To a moderate extent

☐ To a major extent

☐ Cannot participate at all

Appendix C Modified OSTRC Baseline Questionnaire cont'd

Question 4

To what extent have you experienced symptoms during the past week

☐ No symptoms

☐ To a mild extent

☐ To a moderate extent

☐ To a severe extent

What part of the body have you injured? ____