Methodological advances in injury surveillance and injury inciting event analysis in elite UK netball

A Thesis Submitted for the Degree of Doctor of Philosophy

By

Sara Louise Horne

Department of Sport, Health and Exercise Sciences, Brunel University London

2026

Abstract

Injury remains a persistent challenge in netball across all levels of participation, yet limitations in how injuries are defined, captured and described have constrained injury prevention efforts. To address these limitations, this thesis aimed to develop and apply robust methods to enhance injury surveillance and injury-inciting event analysis in elite UK netball, thereby improving methodological consistency and strengthening the injury prevention evidence base. To meet this aim, four interrelated studies were undertaken that synthesised existing evidence, implemented prospective injury surveillance, developed and evaluated a netball-specific injury-inciting event classification system, and piloted a preliminary biomechanical domain to support the system's future extension.

A scoping review demonstrated substantial methodological inconsistency in netball injury research, particularly in injury definitions, exposure measurement and inciting-event reporting. This informed recommendations to improve standardisation and guided the methodological approach adopted in subsequent studies. Prospective injury surveillance in the Vitality Netball Superleague (VNSL) showed match injury incidence was considerably higher than training, with match injuries predominantly acute lower-limb conditions resulting in high time-loss burden, whereas training injuries were largely overuse-related and frequently non–time-loss. Subsequently, the Netball Injury Inciting Event Classification System (NIIECS) was developed and evaluated to classify situational, behavioural and contextual characteristics of injury events using video-based or non-video (athlete- or clinician-reported) data sources. Acceptable inter- and intra-rater reliability and applied usability were demonstrated for video-based match injury events. Finally, a preliminary biomechanical domain was proposed to extend the NIIECS, with expert feedback indicating strong support for the inclusion of biomechanical descriptors while identifying key priorities for refinement to support future development and integration.

Overall, this thesis advances methodological standards for injury surveillance and injury-inciting event analysis in netball. It provides an improved foundation for consistent, context-informed injury monitoring and interpretation in elite UK netball, supporting evidence-informed decision-making to guide injury prevention efforts. This work also establishes a platform for future refinement, including biomechanical integration, to inform targeted injury prevention strategies.

Acknowledgements

This thesis represents the culmination of a doctoral journey undertaken alongside substantial professional and personal commitments, and through periods of unexpected disruption and challenge. Its completion has been sustained by the steady support and reassurance of those who repeatedly reminded me to keep moving forward, for which I am deeply grateful.

Firstly, I would like to express my sincere gratitude to my supervisory team for their guidance and support throughout this PhD. I am especially thankful to my primary supervisor, Dr Laura Hills, for her willingness to support and guide this project from its outset. Over the full duration of the doctorate, she has consistently believed in both the work and in me, often at times when my own confidence wavered. Her advocacy, encouragement and commitment have extended well beyond the requirements of supervision, and her support has been fundamental to the completion of this thesis. I am also deeply grateful to Dr Aliah Shaheen, whose support has taken many forms across the course of this PhD. Her academic guidance, generosity with her time and unwavering support have been invaluable, and her ability to provide both intellectual and personal support has made a significant difference to my doctoral journey. Finally, I would like to thank Professor Bill Baltzopoulos for agreeing to supervise this work. It has been a privilege to benefit from his depth of knowledge and experience, and his contributions have often taken the form of timely insights and carefully considered observations that brought clarity and perspective at key moments in the research.

This research would not have been possible without the cooperation and support of key organisations and individuals across the elite sport system. I would especially like to thank England Netball for agreeing to support this research and for providing permission to examine injury patterns within the VNSL. In particular, I am grateful to Helen Alfano, whose support, guidance and willingness to engage with the project were instrumental during the early stages of data collection. I would also like to acknowledge the support of the England Netball medical team, including Jim Kerss, Julia Snow and Philippa Thompson, whose cooperation, professionalism and commitment throughout the research were central to its successful delivery. In addition, I am grateful to the Athlete Health team at the English Institute of Sport for their assistance in facilitating access to the Player Data Management System (PDMS) data used within this thesis.

I am also grateful to the VNSL clubs and staff for their engagement with this research. In particular, I thank the team physiotherapists for their enthusiasm, responsiveness and patience throughout the data-collection process. I would especially like to acknowledge

Andrew Holbrook, who consistently showed a strong interest in the work and contributed further by participating in the expert consensus process. I am also thankful to the VNSL players who agreed to take part in this research and to share information that underpinned several components of the thesis. Finally, my sincere thanks extend to the researchers, clinicians and medical staff who generously contributed their time and expertise to the consensus process; their willingness to engage critically with the work was essential to the development and validation of the framework presented in this thesis.

On a more personal level, I am very grateful to the friends who encouraged me over the course of my PhD. I particularly wish to thank Lisa, Denise, Belle and Pascale, who were constants throughout this journey and understood the challenges of the research and writing process through their own doctoral and professional experiences. Their ongoing understanding, advice and care made an immeasurable difference, particularly during the more difficult periods. Finally, and most importantly, I would like to thank my very special family, whose constant presence, comfort and reassurance means so much. I am especially grateful to my Mum and Dad, Pauline and Colin, for their unwavering love and belief in me. My Dad is not with us to see the completion of this thesis, but his encouragement and quiet confidence in me remain with me always. To my Mum, whose strength and steady reminders to simply keep going sustained me throughout, I owe more than words can express.

Publications

Horne, S., Shaheen, A. F., Baltzopoulos, B., & Hills, L. (2024). The netball injury evidence base: A scoping review of methodologies and recommendations for future approaches. *Systematic Reviews, 13*(1), 203. https://doi.org/10.1186/s13643-024-02629-7

Horne, S., Shaheen, A. F., Baltzopoulos, B., & Hills, L. (2025). Match and training injury epidemiology in elite UK netball: A prospective cohort study over one season. *BMJ Open Sport & Exercise Medicine, 11*(1), e002324. https://doi.org/10.1136/bmjsem-2024-002324

Horne, S., Shaheen, A. F., Baltzopoulos, B.,…, & Hills, L. (2026). Development of a standardised system to identify injury-inciting events in netball: The Netball Injury Inciting Event Classification System (NIIECS). Manuscript submitted for publication.

Conference presentations

Horne S, Hills, L, Shaheen, A and Baltzopoulos. (2022). Methodological approaches for the assessment of injury risk factors and mechanisms in elite Netball. *9th World Congress of Biomechanics*, Taipei, Taiwan, July 2022.

Horne S, Hills, L, Shaheen, A and Baltzopoulos. (2021). Methodological approaches for the assessment of injury risk factors and mechanisms in elite Netball. *7th Postgraduate Researchers Conference*, Brunel University, December 2021.

Horne S, Hills, L, Shaheen, A and Baltzopoulos. (2019). Vitality Netball Superleague 2019 Injury Surveillance Findings. *9th Vitality Netball Superleague Conference*, Derby, November 2019.

Horne S, Hills, L, Shaheen, A and Baltzopoulos. (2018). Assessment of injury risk factors and mechanisms in elite netball. *8th Vitality Netball Superleague Conference*, Derby, November 2018.

Reports

Horne S, Hills, L and Baltzopoulos. (2019). Vitality Netball Superleague 2019 Injury Surveillance Report. Submitted to England Netball on 20/9/2019 (Appendix E)

Horne S, Hills, L, Shaheen, A and Baltzopoulos. (2021). Vitality Netball Superleague 2021 Injury Surveillance Report. Submitted to England Netball on 10/1/2021 (Appendix E)

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List of Abbreviations

ACL	Anterior Cruciate Ligament
ANZ	Australia and New Zealand (Banking Group)
CART	Classification and Regressions Trees
CHAMP	Checklist for the statistical assessment of medical papers
CI	Confidence Interval
CREDES	Conducting and REporting DElphi Studies
CV	Coefficient of Variation
EIS	English Institute of Sport
I	Incidence
ICD	International Classification of Diseases
IOC	International Olympic Committee
MA	Medical Attention
M-FASIS	Multistate Framework for the Analysis of Subsequent Injury in Sport
NIIECS	Netball Injury Inciting Event Classification System
OSICS	Orchard Sports Injury Classification System
OSIICS	Orchard Sports Injury and Illness Classification System
OSTRC	Oslo Sports Trauma Research Center
PDMS	Player Data Management System
PRISMA-ScR	Preferred Reporting Items for Systematic reviews and Meta-analyses extension for Scoping Reviews
TIP	Team-Sport Injury Prevention Cycle
TL	Time-Loss
TRIPP	Translating Research into Injury Prevention Practice
RD	Restricted Days
RTP	Return to Play
SIC/SIC-2.0	Subsequent Injury Categorisation
SSN	Suncorp Super Netball
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology
STROBE-SIIS	Strengthening the Reporting of Observational Studies in Epidemiology – Sports Injury and Illness Surveillance
UK	United Kingdom
VNSL	Vitality Netball Superleague

Chapter 1: Introduction

Participation in sport provides a range of physical, psychological, and social benefits. It is a key component of a healthy lifestyle, contributing to disease prevention, improved mental well-being, and enhanced social connectedness, particularly in team-based settings (Bengtsson et al., 2025; Eime et al., 2013; Warburton & Bredin, 2017). However, sport also carries a substantial risk of injury, with both immediate and long-term consequences for individuals, including time lost from participation, reduced quality of life, re-injury, and chronic conditions such as osteoarthritis (Bullock et al., 2020; Carbone & Rodeo, 2017). Injuries can also disrupt player availability and team success (Drew et al., 2017; Hägglund et al., 2013; Williams et al., 2025) and at a population level, contribute significantly to healthcare and economic burden (Ponkilainen et al., 2022; Turnbull et al., 2024). These wide-ranging consequences highlight the global public health challenge of sports injuries and the critical need for effective, evidence-based prevention strategies to ensure the benefits of participation are not outweighed by avoidable harm.

In the United Kingdom (UK), an estimated 3.6 million adults sustain sport-related injuries each year, equating to approximately 10,000 cases per day (Podium Analytics, 2023). Between 2012 and 2017, over 11,700 major trauma hospital admissions attributable to sport were recorded in England and Wales, with an annual incidence of 5.4 injuries per 100,000 people; 28% were classified as severe and 1.3% fatal (Davies et al., 2024). The economic impact of such injuries is considerable, with NHS treatment recovery costs, for all injuries including sports, exceeding £170 million in 2022-2023 (Department of Health and Social Care, 2023). In elite male sports, injury costs surpassed £276 million from 915 injuries during the 2023–24 English Premier League season (Howden, 2024), and over £167,000 per team per season in professional cricket (Williams et al., 2025). In contrast, the cost of injuries in women's sport in the UK is largely undocumented. However, in New Zealand, women's rugby union injuries were estimated to cost over £8 million across five years, with knee and concussion injuries accounting for a significant share (King et al., 2019a). Despite the high injury burden and growing participation in women's sport, prevention efforts have largely focused on men. Women's team sports remain under-researched, with injury strategies often based on male data, overlooking the unique risk profiles of female athletes (Gilhooly et al., 2023).

Netball is a court-based sport played between two teams of seven players, who compete to gain and retain possession of the ball to score goals in a 10-foot hoop. Primarily played by women, the sport is particularly popular across Commonwealth nations, with over 20 million participants worldwide, spanning 117 countries across five regions including Africa, the Americas, Asia, Europe, and Oceania (World Netball, 2024). It is the leading women's sport in Australia (1,017,000 participants; Netball Australia, 2023) and New Zealand (300,000; Netball New Zealand, n.d.), with approximately 345,000 players in England (Statista, 2025). The standard 7-a-side format is played from junior to international levels, alongside modified versions such as indoor, walking, and Fast5 netball. At the elite level, major competitions include the Netball World Cup, Commonwealth Games and Fast5 World Series, supported by professional domestic leagues in Australia (Suncorp Super Netball), New Zealand (ANZ Premiership), and the UK (Netball Superleague). The UK's top domestic league, established in 2005–06 and organised by England Netball, features franchises based across England and Wales (and previously Scotland) and attracts international players from a range of nations. Since its inception, the league has evolved through several competition formats and periods of expansion, including growth from eight to eleven teams. In 2025, the league was relaunched as part of a wider professionalisation programme (Netball Super League, n.d.).

Netball is a fast-paced, intermittent sport characterised by frequent activity changes, alternating between high-intensity bursts, lower-intensity actions, and brief rest periods (Davidson & Trewartha, 2008; Fox et al., 2013; Mackay et al., 2025; van Gogh et al., 2020). This stop-start nature makes the sport primarily anaerobic, although a well-developed aerobic capacity is essential to sustain performance across a standard 60-minute match played in four 15-minute quarters (Thomas et al., 2017). The seven playing positions have distinct roles and operate in specific court zones, leading to varying physical demands (Bailey et al., 2017; Brooks et al., 2020a; van Gogh et al., 2020), however, all players perform fundamental movement patterns. These include repeated explosive accelerations and decelerations, quick multidirectional movements, frequent jumping and landing on one or both legs, and continuous passing and catching actions executed within a 3 second time-constraint (Fox et al., 2013; Thomas et al., 2017). Such movements typically occur under considerable defensive pressure, in restricted spaces, and on various playing surfaces, usually indoor sprung timber or synthetic courts at the highest levels (Downs et al., 2021). The combination of these high physical demands, and netball's unique footwork rule, which requires rapid deceleration to stop within 1.5 steps after gaining possession, causes substantial mechanical loading (Otago, 2004; Steele, 1990; Stuelcken et al., 2013) and high player workloads (Bailey et al., 2017; Brooks et al., 2020a; Mackay et al., 2025; Simpson et al., 2020; Young et al., 2016). Consequently, injury incidence in netball is high, particularly at the elite level (Downs et al., 2021; Whitehead et al., 2021).

Injury research to date reports netball incidence rates typically ranging from 11.3 to 19.4 injuries per 1000 player hours across all levels of play (Downs et al., 2021). However, substantially higher rates have been documented in elite tournament settings, with the 2019 Netball World Cup reporting 54.8 injuries per 1000 player-hours (Janse van Rensburg et al., 2022). These rates exceed those observed in other elite women's team sports, including basketball (Deitch et al., 2006), rugby (King et al., 2019b), and soccer (Mayhew et al., 2021), highlighting the high injury burden in netball. The majority of netball injuries involve the lower limb, particularly the ankle and knee (Downs et al., 2021; Whitehead et al., 2021). Lateral ankle ligament sprains are most common, accounting for approximately 40% of all reported cases, and frequently lead to recurrence and chronic ankle instability (Attenborough et al., 2016; Rowe et al., 2021). Although less prevalent, knee injuries, particularly anterior cruciate ligament (ACL) ruptures, are typically more severe, resulting in prolonged time-loss and substantial rehabilitation costs (Belcher et al., 2020; Downs et al., 2021; Langeveld et al., 2012; Toohey et al., 2022). Many of these injuries are linked to poor landing mechanics, often including player contact (Downs et al., 2021; Stuelcken et al., 2016, 2024). Given the high incidence and potentially long-lasting consequences of these injuries, there is a clear need for robust and effective prevention strategies. Yet current evidence-based programmes remain limited, inconsistently implemented, and frequently lack rigorous evaluation (Downs et al., 2021; Rowe et al., 2021; Saad et al., 2021; Whitehead et al., 2021).

Sports injuries are widely recognised as a preventable public health concern (Ekegren et al., 2015; Stephenson et al., 2021). In response, structured approaches have been developed to guide injury prevention research. The seminal framework is the four-step Sequence of Prevention proposed by van Mechelen et al. (1992), which begins by identifying the extent of the injury problem through measures of incidence and severity (Step One), followed by investigation of injury aetiology (risk factors) and injury mechanisms (the circumstances in which injuries occur) (Step Two). This evidence informs the development of targeted prevention strategies (Step Three), which are evaluated by repeating Step One to assess effectiveness (Step Four) (Figure 1.1). Several models have built upon this framework, including the Translating Research into Injury Prevention Practice (TRIPP) model (Finch, 2006), which recognised the gap between research and real-world practice, by incorporating contextual factors affecting implementation (Step Five) and evaluation of effectiveness in real-world settings (Step Six) (Figure 1.1). More recently, O'Brien et al. (2019) proposed the Team-Sport Injury Prevention (TIP) cycle (Figure 1.2), comprising three iterative phases: (re)evaluate, identify, and intervene. Unlike the linear models, TIP integrates injury surveillance, risk factor and injury causation analysis, and practical constraints as ongoing, interconnected processes, better reflecting the daily realities of team sport. Despite these structural differences, all models consistently emphasise the need for robust, sport-specific evidence to inform effective prevention.

Model Stage	SEQUENCE OF PREVENTION (van Mechelen et al., 1992)	TRIPP MODEL (Finch, 2006)
1	Establish extent of the problem	Injury Surveillance
2	Establish aetiology and mechanisms of injury	Establish aetiology and mechanisms of injury
3	Introduce preventative measures	Develop preventative measures
4	Assess their effectiveness by repeating stage 1	"Ideal condition"/scientific evaluation
5		Describe intervention context to inform implementation strategies
6		Evaluate effectiveness of preventive measures in implementation context

Figure 1.1 *Adapted from the sequence of prevention of sports injuries* (van Mechelen et al., 1992) *and the Translating Research into Injury Prevention (TRIPP) framework* (Finch, 2006)

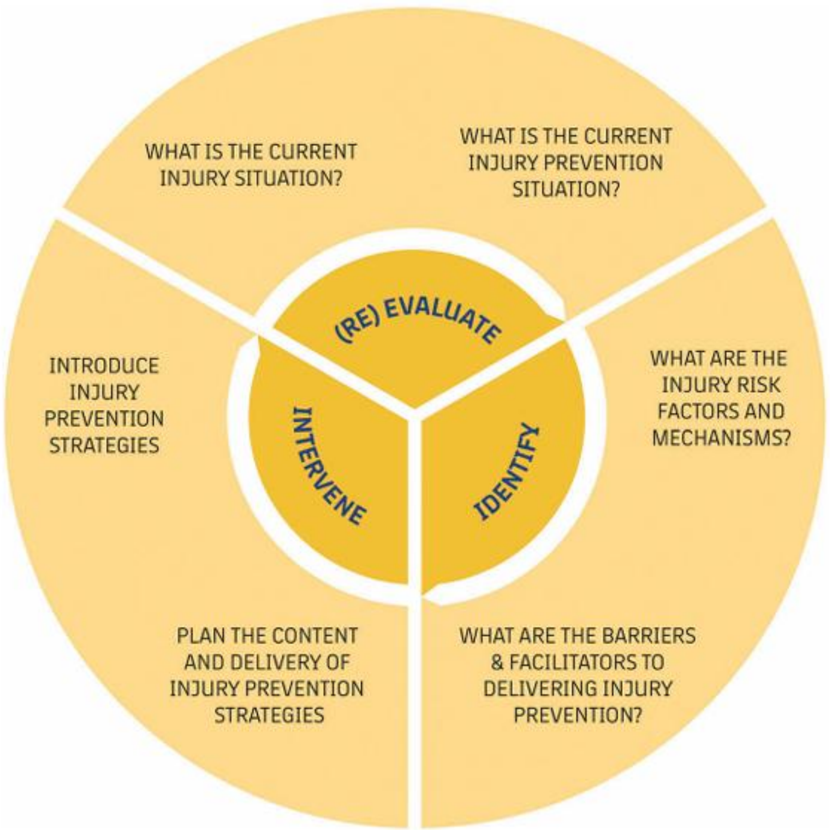

Figure 1.2 *The Team-sport Injury Prevention (TIP) cycle* (O'Brien et al., 2019)

If the effectiveness of injury prevention strategies ultimately depends on the quality of the evidence underpinning them, then it requires standardised methods of data collection and analysis. Step One, commonly described as descriptive injury epidemiology, focuses on establishing the scale and distribution of the problem by quantifying the incidence, severity, and burden of injuries. The accuracy of this stage depends on high-quality data from ongoing, systematic surveillance systems. Although considerable research has been conducted, the absence of robust surveillance systems across many sports has hindered accurate identification of injury patterns (Bahr et al., 2020; Brooks & Fuller, 2006; Ekegren et al., 2015). Step Two involves analytic epidemiology, which seeks to explain why injuries occur by examining underlying risk factors and the injury-inciting event. The latter refers to the immediate circumstances in which injury occurs, including the playing situation and athlete/opponent behaviours, and the associated biomechanical loading at the moment of injury (Bahr & Krosshaug, 2005). However, limited understanding of these causal processes has restricted the development of targeted interventions, hence many prevention strategies have been implemented without sufficient evidence of why athletes are at risk and how injuries occur (Bahr & Krosshaug, 2005).

To address these limitations, injury research has increasingly prioritised methodological developments to improve the accuracy and reliability of both descriptive and analytic data. Generic and sport-specific consensus statements have been developed to standardise injury definitions, surveillance protocols, and reporting practices (Bahr et al., 2020). Furthermore, researchers have emphasised the need to examine the playing context and player interactions, together with the underlying biomechanical mechanisms, to fully understand the injury-inciting event (Bahr & Krosshaug, 2005; Krosshaug et al., 2005). Advances in video analysis have enabled detailed investigation of these injury-inciting events in real-game contexts (Belcher et al., 2022), and frameworks for standardised video-based reporting are emerging across sports (Hendricks et al., 2016; Mackay et al., 2023). At the same time, recognition of injury as a complex, dynamic process has shifted research away from traditional linear cause–effect models toward complex systems approaches that consider the interplay of multiple interacting risk factors contributing to an athlete’s overall injury risk profile (Bittencourt et al., 2016; Bolling et al., 2018).

Given these methodological advances, there is an urgent need to re-evaluate the injury evidence base across sports. Despite a growing body of research in netball, the quality and consistency of existing evidence remain limited (Downs et al., 2021; Mackay et al., 2023). Most studies over the past 30 years have focused on descriptive epidemiology (Step One), with far fewer examining injury aetiology and causal pathways, including the circumstances of injury occurrence (Step Two) (Whitehead et al., 2021). However, a lack of widespread systematic surveillance, alongside inconsistent injury definitions and methodological variability, has hindered the establishment of a coherent understanding. At the same time, simplified accounts of how injuries occur and selective attention to particular risk factors have further inhibited progress (Mackay et al., 2023; Whitehead et al., 2021). Much of this work was also conducted prior to recent developments in the sport, including the 2016 rule changes and the increasing speed and demands of elite competition (Simpson et al., 2019). Despite the visibility and professionalisation of the UK Vitality Netball Superleague (VNSL), no peer-reviewed studies have examined injuries within this competition, with most current evidence drawn from Australia and New Zealand. Addressing this gap, the present thesis was undertaken in collaboration with England Netball to support the implementation of contemporary, context-specific injury surveillance and injury-inciting event methods within elite UK netball. Specifically, the methodological advances sought by the thesis were to improve the consistency and comparability of injury surveillance practices, enhance the practical utility of injury surveillance data, develop and evaluate a standardised framework for classifying injury-inciting events, and establish a foundation for the future integration of biomechanical descriptors into injury-inciting event analysis.

The rationale for this programme of research was additionally informed by the author's applied and research involvement in elite sport environments, including work within Netball Superleague and Scotland national squads, and injury-focused research collaborations with the Football Association and World Netball. This experience provided direct insight into the real-world constraints of injury monitoring workflows and data availability in applied settings, as well as the limitations of existing approaches for describing injury onset in a consistent and prevention-relevant manner. This embedded perspective strengthened the methodological design of the thesis, ensuring that the programme of work remained grounded in real-world feasibility and end-user requirements within applied netball environments. Accordingly, this thesis seeks to strengthen the accuracy and consistency of the netball injury evidence base and to support the ongoing professionalisation of the VNSL through standardised surveillance procedures and classification methods capable of informing meaningful, evidence-based prevention strategies.

In summary, elite UK netball has been characterised by limited injury surveillance practices and insufficient assessment of how injuries occur. The lack of consistent, prospective surveillance and the absence of standardised methods for analysing injury-inciting events have restricted the development of a robust, sport-specific evidence base. These methodological shortcomings have, in turn, hindered the identification of injury patterns, understanding of injury causation, and the design of targeted prevention strategies. Addressing these foundational issues requires methodological advances that strengthen both the systematic collection of injury data and the analysis of the circumstances surrounding injury events.

1.1 Aims of the Thesis

The overarching aim of this thesis was to develop and apply robust methodological approaches in order to improve the accuracy and consistency of the netball injury evidence base. Specifically, the research sought to advance methods of injury surveillance and improve approaches for analysing injury-inciting events in elite UK netball. To address this aim, four interrelated studies were undertaken:

1. To conduct a scoping review evaluating the range and characteristics of netball injury research methodologies and to provide recommendations for future research (Study One / Paper I).

2. To implement a systematic injury surveillance system in the Vitality Netball Superleague and describe the incidence, types, mode of onset (acute/overuse), mechanism of onset (contact/non-contact) and impact (severity and burden) of match and training injuries across one competitive season (Study Two / Paper II).

3. To develop and validate a standardised classification system for describing injury-inciting events in netball, encompassing match injuries (playing situation, player and opponent behaviours), training injuries, and injuries without a clearly identifiable inciting event (Study Three / Paper III).

4. To pilot the development of a biomechanical domain for the classification system, providing preliminary insights into biomechanical descriptors relevant to injury-inciting events and informing future consensus processes (Study Four).

1.2 Overview of Studies

Study One (Chapter 3) presents a comprehensive scoping review of existing netball injury research. It evaluates the methods used to describe injury epidemiology, and injury aetiology and causation, including risk factor assessment and approaches used to operationalise injury causation through mechanism of onset descriptors and injury-inciting event analysis. Given the limited methodological scrutiny within the field, the review generates evidence-informed recommendations to guide future injury research in netball.

Study Two (Chapter 4) applies the scoping review recommendations by analysing injury data collected through the first systematic surveillance system implemented in the UK Vitality Netball Superleague. This study provides detailed insights into the incidence, types, injury circumstances, and consequences of match and training injuries, enabling the first meaningful comparison of injury patterns within elite UK netball.

Study Three (Chapter 5) addresses the absence of a comprehensive, standardised framework for describing injury-inciting events in netball. A novel classification system was developed and validated to capture injuries occurring in match and training contexts, as well as those without a clearly identifiable inciting event. The framework incorporates structured descriptors of the playing situation and player–opponent behaviours.

Study Four (Chapter 6) builds on the work of Chapter 5 by piloting the development of a biomechanical domain for the classification system. This study explores how biomechanical descriptors can be systematically represented within the framework, offering preliminary insights to support future consensus development and methodological refinement. Together, Studies Three and Four establish the first netball-specific injury-inciting event classification framework and outline a staged pathway for integrating biomechanical descriptors.

Collectively, these studies strengthen the methodological foundations of netball injury research and provide a platform for developing more targeted, evidence-based prevention strategies.

1.3 Thesis Format and Structure

This thesis is presented in a PhD by publication format and is organised into eight chapters. The primary original contributions are contained within the four studies, with the surrounding chapters providing critical context, integration, and synthesis across the programme of research. Chapter 1 introduces the research aims and provides an overview of the studies undertaken. Chapter 2 presents a critical review of the methodological foundations of sports injury epidemiology and causation, with a particular focus on netball. Chapters 3–6 report the four interrelated studies that address the thesis aims. Chapter 3 details the scoping review of existing netball injury research. Chapter 4 describes the implementation of a systematic injury surveillance system in the Vitality Netball Superleague and reports the resulting epidemiological findings. Chapter 5 presents the development and validation of the Netball Injury Inciting Event Classification System. Chapter 6 reports the pilot study exploring the development of a biomechanical domain for the classification framework. Chapter 7 synthesises the findings across studies and discusses their theoretical, methodological and practical implications. Finally, Chapter 8 provides the overall conclusion of the thesis, highlighting its key contributions and outlining directions for future research, policy and practice.

Chapter 2: Literature Review

This chapter provides a critical review of the methodological foundations and existing evidence on sports injury epidemiology and causation, with a particular focus on netball. It begins by outlining current definitions and classifications of sports injuries before examining contemporary approaches to injury epidemiology and surveillance. The chapter then considers theoretical frameworks and analytical methods used to investigate injury causation, with emphasis on the study of injury-inciting events and underlying biomechanical factors. The final section focuses on netball, summarising its physical demands and synthesising current knowledge on injury epidemiology and injury inciting-events. Across all sections, key limitations and gaps in the evidence are highlighted to establish the rationale for the thesis and guide the methodological approaches adopted in subsequent chapters.

2.1 Methodological Foundations of Sports Injury Research

Epidemiology is defined as the study of the distribution and determinants of health-related events in specified populations, and its application for their prevention (Porta et al., 2014). In the sporting context, sports injury epidemiology is concerned with the distribution and determinants of injuries in athletic populations. It encompasses both descriptive research, which uses surveillance systems to quantify the incidence, severity, and burden of injuries, and analytic research, which investigates risk factors and injury causation. These directly align with the first two steps of the injury prevention models: (1) identifying the extent of the injury problem through surveillance, and (2) understanding its aetiology by examining risk factors and the circumstances in which injuries occur (Finch, 2006; O'Brien et al., 2019; van Mechelen et al., 1992), thereby providing the evidence base needed to develop effective prevention strategies.

As outlined in Chapter 1, effective sports injury prevention depends on the use of accurate, consistent data and robust analytical methods in injury epidemiology. However, research has historically used varied definitions, data collection procedures and analytical approaches, creating inconsistencies that hinder cross-study comparisons, limit trend identification, and reduce the ability to establish causation and implement targeted prevention strategies (Bahr & Holme, 2003; Brooks & Fuller, 2006; Krosshaug et al., 2005). Over the past two decades, substantial methodological progress has been achieved through cross-sport consensus statements, such as the International Olympic Committee (IOC) statements of Junge et al. (2008) and Bahr et al. (2020), and sport-specific statements in football (Fuller et al., 2006; Waldén et al., 2023), rugby (Fuller et al., 2007; King et al., 2009), cricket (Orchard et al., 2005, 2016), tennis (Pluim et al., 2009; Tooth et al., 2025; Verhagen et al., 2021), aquatic sports (Mountjoy et al., 2016), athletics (Timpka et al., 2014), golf (Murray et al., 2020) and competitive cycling (Clarsen et al., 2021). Many of these built on the IOC framework (Bahr et al., 2020), including a dedicated statement on female athlete health (Moore et al., 2023). Collectively, these statements provide standardised definitions and surveillance methods and are complemented by broader research quality initiatives, including the general STROBE guideline for observational studies (Von Elm et al., 2007), its sport-specific extension STROBE-SIIS (Bahr et al., 2020) and the EQUATOR Network (n.d.), which promote transparency, comparability, and reproducibility in health research. At the same time, theoretical frameworks have advanced understanding of injury causation, highlighting the multifactorial and complex nature of sports injuries and shifting analysis beyond simple linear models (Bahr & Krosshaug, 2005; Bittencourt et al., 2016; Meeuwisse et al., 2007). This section reviews these methodological foundations to frame the subsequent netball-specific analysis (Section 2.2).

2.1.1 Defining Sports Injuries

A fundamental component of the methodological advances in sports injury epidemiology has been the development of clear, standardised definitions of injury. Defining injuries in sport is inherently challenging and has been extensively debated over many years (Langley & Brenner, 2004). Despite this complexity, both theoretical and operational definitions have been established to guide research. Theoretical definitions are now generally based on the "energy definition" proposed by Haddon (1973), which in sport has been adapted to describe injury as tissue damage or other disruption of normal physical function, occurring during sports participation and caused by the rapid or repetitive transfer of kinetic energy (Bahr et al., 2020). While this provides a conceptual foundation, translating theory into measurable criteria for systematic data collection requires clear operational definitions. These determine which events are recorded as injuries and how their severity and classification are defined (Fuller, 2010), shaping the accuracy of both injury surveillance and subsequent analyses of injury causation, which represent the first and second steps of the injury prevention models (Finch, 2006; O'Brien et al., 2019; van Mechelen et al., 1992).

The consensus statements across sports provide broad guidance on operational definitions, typically distinguishing between time-loss injuries (where the athlete cannot participate), medical attention injuries (requiring professional evaluation), and all-complaints approaches (recording any physical problem regardless of consequence). Each definition has strengths and limitations, with time-loss definitions supporting reliable comparisons but under-reporting minor and overuse injuries, while broader definitions capture the full burden, but may reduce reliability and increase data collection demands (Bahr, 2009; Clarsen & Bahr, 2014; Hägglund et al., 2005; Orchard & Hoskins, 2007). Inconsistencies in operational definitions are a major source of variability in the sports injury literature, directly affecting incidence, burden, and comparability of findings. For example, Clarsen et al. (2012) and Bahr (2009) showed that broader, all-complaints approaches capture substantially more overuse and minor injuries with time-loss definitions systematically underestimating their occurrence. Cross et al. (2018) established that applying different definitions within the same dataset can yield markedly different incidence rates. Similarly, in rugby league, missed-match definitions underestimated injury rates compared with medical-attention or all-complaints criteria (King et al., 2009). The research suggests no single operational definition is appropriate for all contexts, and the choice should be guided by the study's aims, population, and setting (Clarsen & Bahr, 2014; Ekegren et al., 2015), yet there is also a parallel need for consistency to enable meaningful comparisons within and across sports. Balancing these demands is therefore critical as the definition applied directly shapes the injury patterns reported, with significant consequences for the accuracy of surveillance and the design of effective prevention strategies.

2.1.2 Injury Classifications

In addition to establishing a clear injury definition, the systematic classification of injuries by mode (acute/overuse) and mechanism of onset (contact/non-contact), as well as the recurrence, severity, burden, body area, tissue type, and diagnosis, is essential for producing meaningful and comparable epidemiological data. Standardised classification not only enables accurate description of injury patterns within a sport but also supports valid comparisons across different sports and settings, forming the foundation for effective surveillance and prevention strategies.

2.1.2.1 Mode and Mechanism of Injury Onset. Classifying injuries by their mode and mechanism of onset is important to distinguish their underlying causes, patterns of development, and management requirements. Such distinctions improve the accuracy of surveillance data, enable meaningful comparisons across studies and sports, and inform both prevention and rehabilitation strategies (Hespanhol et al., 2015). Consensus statements typically classify injuries as arising either from a single, identifiable event or from cumulative loading over time. A range of terminology has been used to describe the mode of onset, with the former referred to as acute, traumatic, or sudden-onset injuries, occurring when an external force or transfer of energy produces an immediate injury (e.g., awkward landing leading to a ligament rupture). In contrast, the latter, classified as overuse or gradual-onset injuries, develop progressively as a result of repetitive sub-maximal loading without a single identifiable incident, often manifesting in conditions such as tendinopathy or bursitis (Bahr et al., 2020). More recently, this dichotomy has been refined by recognising that overuse injuries may present with either sudden or gradual onset, since symptoms can appear abruptly despite being caused by cumulative tissue damage (Bahr et al., 2020; Clarsen et al., 2021; Moore et al., 2023; Mountjoy et al., 2016; Murray et al., 2020; Timpka et al., 2014).

In addition to mode of onset, consensus statements recommend classifying injuries by their mechanism of onset, typically using the broad categories contact and non-contact in injury surveillance studies (Fuller et al., 2007; Junge et al., 2008). Contact injuries result from interaction with another player or object (e.g., collision, tackle, ball, post), while non-contact injuries occur without external impact, often during sudden changes of direction, landing, or deceleration. Bahr et al. (2020) further subdivided contact mechanisms of onset into direct, where force is applied directly to the injured body part, and indirect, where force is applied elsewhere and transmitted to the injury site (e.g., being pushed in the upper body leading to a twisting knee injury). While these categories provide a useful framework, inconsistent use of terminology and lack of clear definitions across the literature has reduced comparability between studies (Bahr et al., 2020). Thus, although classifications by mode of onset (acute vs. overuse) and mechanism of onset (contact vs. non-contact) form the essential categories for sports injury surveillance, they should be applied with care and transparency. These categories, however, represent only an initial level of description. A more detailed analysis of the inciting event and underlying biomechanical mechanisms, critical for understanding injury causation, will be addressed in Section 2.1.4.

2.1.2.2 Subsequent Injury. Accurately classifying whether an injury is new or related to a previous one is essential for calculating valid incidence rates and consequently the identification of risk factors and injury causation to inform targeted prevention programmes. Across a season, athletes may sustain no injuries, one, or more than one related or unrelated injuries hence, whether the injury is a new, “index” injury or a subsequent injury is an important consideration. Previous injury is a well-established risk factor for further injury, often due to incomplete recovery, persistent tissue weakness, or exposure to similar risk factors and injury-inciting events (Hägglund et al., 2006; Hamilton et al., 2011; Meeuwisse et al., 2007). Despite this, the relationship between initial and subsequent injuries is often poorly captured in surveillance systems, with inconsistent terminology and limited differentiation beyond simple recurrence at the same site and type (Finch & Cook, 2014; Fortington et al., 2017).

Early consensus statements defined recurrent injury as the same type and site as a previous “index” injury following return to full participation (RTP), categorising them by time as early (≤2 months post-RTP), late (2–12 months), or delayed (>12 months) (Fuller et al., 2006, 2007; Orchard et al., 2005). Fuller et al. (2007) further distinguished between reinjury (index injury fully healed) and exacerbation (not fully healed), incorporating both location and tissue type into their classification. Hamilton et al. (2011) expanded this framework to define "subsequent injury" as any injury following an index injury within the dataset, further classifying these as subsequent new injuries (different location), local injuries (same location, different type), or recurrent injuries (same site and type), with the latter subdivided into reinjuries and exacerbations (Figure 2.1). More recent models address limitations in capturing overuse injuries, which often lack a discrete onset and present fluctuating symptoms. The Subsequent Injury Categorisation (SIC) model (Finch & Cook, 2014) and its update, SIC-2.0 (Toohey et al., 2018), provide more detailed dependency categories, while the Multistate Framework for the Analysis of Subsequent Injury in Sport (M-FASIS) (Shrier et al., 2016) focuses on transitions in athlete health states. While these models improve accuracy and facilitate advanced statistical analyses, they require substantial expertise, resources, and consistent application to be effective in routine surveillance. Consequently, the IOC consensus (Bahr et al., 2020) and recent football consensus (Walden et al., 2023) recommend the Hamilton et al. (2011) framework for most injury research.

2.1.2.3 Injury Severity. The severity of injuries provides essential context for understanding their impact on athletes and teams and for prioritising prevention strategies. Severity classification offers a standardised way to describe the extent of an injury's consequences, facilitating comparison within and across sports. Numerous definitions have been applied in the literature, with severity variously classified according to injury nature, treatment type or duration, time lost from sport or work, permanent damage, and economic cost (Finch et al., 1997; van Mechelen et al., 1997). Of these, time-loss from participation (the number of days from injury to full return to unrestricted training and match play) is the most widely recommended method in sport-specific consensus statements (Fuller et al., 2006; Fuller et al., 2007; Junge et al., 2008; Pluim et al., 2009; Timpka et al., 2014; Mountjoy et al., 2016; Bahr et al., 2020; Walden et al., 2023; Moore et al., 2023). Although rugby league guidelines proposed a simpler "missed match" definition (King et al., 2009), this risks underestimating minor injuries. Hence, the time-loss method remains most widely used. A variety of severity grades have been applied, but recent guidelines recommend standard categories of 0 days (return the same or next day), 1–7 days, 8–28 days, and >28 days' time-loss, with additional classification of catastrophic injury for permanent disability and fatal injury for death (Bahr et al., 2020; Walden et al., 2023). Clear criteria for "full recovery" are essential when applying this method, to ensure accuracy in both severity classification and subsequent injury reporting.

Time-loss measures of severity are appropriate for acute injuries with a clearly defined absence period, but they do not fully capture injuries that do not result in complete absence from sport, including cases where athletes return before full recovery, continue to train or

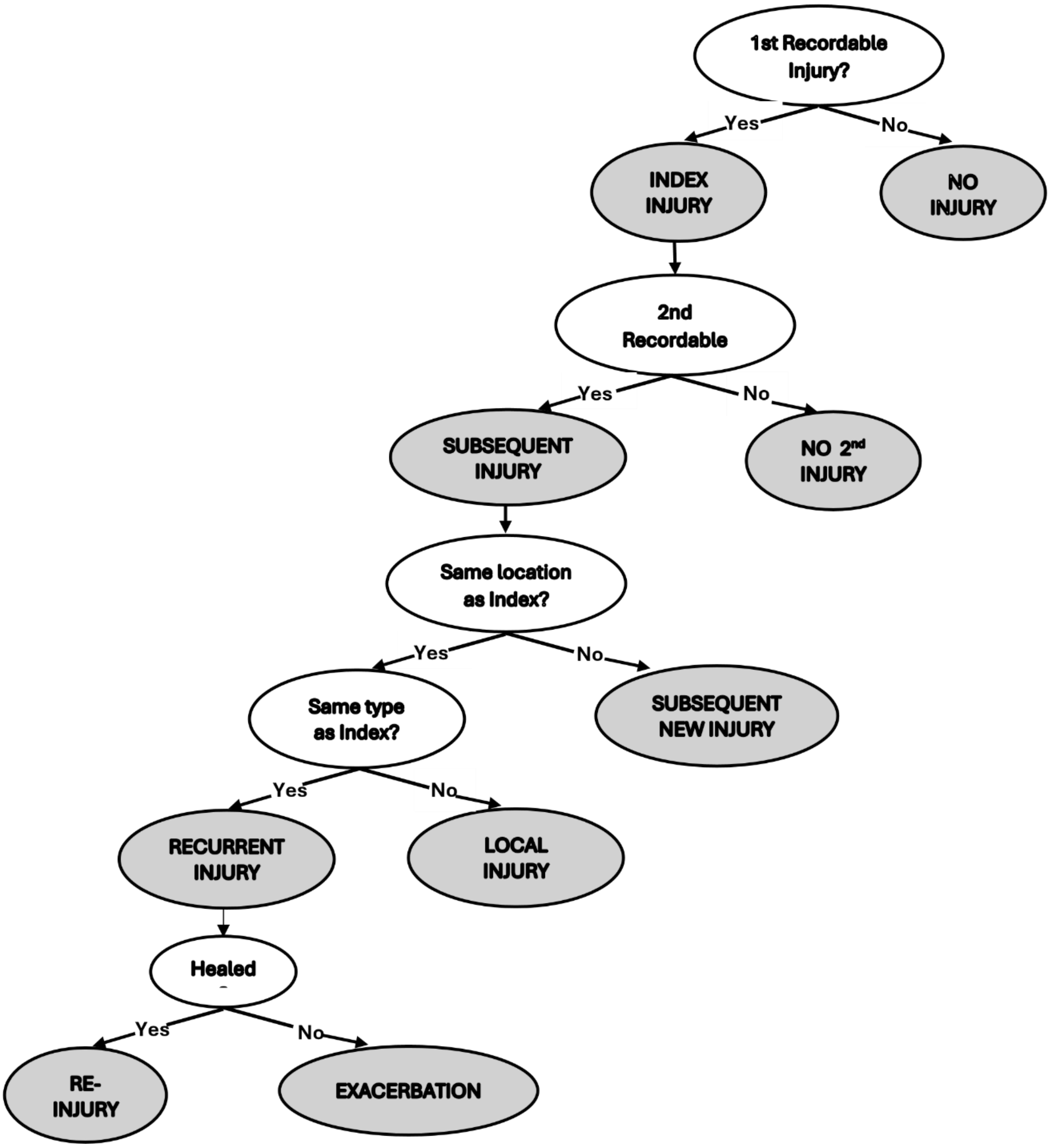

Figure 2.1 *Subsequent Injury Classification System (adapted from* Hamilton et al., 2011)

compete with symptoms, or sustain overuse injuries managed without time-loss (Bahr, 2009; Bahr et al., 2020; Clarsen et al., 2013). In elite sport, athletes may continue participating despite persistent pain, swelling, stiffness, instability, reduced strength, limited range of motion, or reduced agility, all of which may impair performance and increase reinjury risk (Bahr, 2009; Clarsen et al., 2013). Consequently, reliance on time-loss alone may underestimate the true impact of injuries, particularly those requiring ongoing medical attention and/or modified participation rather than complete withdrawal from sport. To address this, recent consensus statements emphasise the value of broader measures of injury consequence, including the need for medical attention, the extent of restricted or modified training and competition participation, and athlete-reported symptom and functional impact (Timpka et al., 2014; Mountjoy et al., 2016; Bahr et al., 2020; Clarsen et al., 2021; Moore et al., 2023; Casey et al., 2024). In such cases, severity may be quantified using complementary indicators such as symptom duration, the number of days requiring medical attention, the duration of restricted or modified training and competition participation, and athlete-reported reductions in function or performance (Bahr et al., 2020; Casey et al., 2024). These approaches are particularly relevant for overuse injuries and other non–time-loss conditions, where severity may be better reflected by symptom duration, ongoing medical management, reductions in training volume or performance, and modified participation, rather than by absence alone. Accordingly, the most appropriate measure of injury severity should be selected according to the aims of the surveillance system and the research question being addressed (Bahr et al., 2020). One important approach to capturing this broader impact is the use of athlete-reported outcome measures such as the Oslo Sports Trauma Research Center (OSTRC) Overuse Injury Questionnaire, updated in 2020 to quantify pain severity, functional limitations, participation restriction and performance reduction through regular athlete self-report (Clarsen et al., 2013; Clarsen et al., 2020). The 2020 update also introduced a cumulative severity score, calculated as the sum of severity scores across repeated assessments, to reflect the total impact of an injury over time, although this remains an arbitrary metric that has not yet been fully validated (Clarsen et al., 2020; Bahr et al., 2020). While valuable for identifying the burden of overuse and other non–time-loss health problems, athlete-reported approaches also present practical challenges, including the need for frequent data collection, potential effects on compliance, and reduced comparability with studies relying solely on clinician-recorded time-loss definitions (Clarsen et al., 2020). Accordingly, whichever method is used to quantify injury severity, its selection should be guided by the research question, the type of injuries of interest, and the practical context in which surveillance is undertaken.

2.1.2.4 Injury Burden. Injury burden has more recently emerged as an important extension of traditional severity classifications, integrating both the frequency and severity of injuries to quantify their overall impact on athletes, teams, and competitions. Unlike incidence or severity considered in isolation, burden provides a more comprehensive indicator of how injuries affect performance and participation, often expressed as time lost per 1000 player-hours (Bahr et al., 2018; Bahr et al., 2020). Including burden as a classification is therefore critical for prioritising prevention strategies, as injuries with relatively low incidence but high time-loss, such as anterior cruciate ligament (ACL) ruptures, contribute more heavily to the overall burden than their frequency alone would suggest, while in many sports, common short-duration injuries may contribute less than incidence figures imply (Bahr et al., 2018).

Although burden is conceptually positioned here within injury classifications, the detailed methodological approaches for quantifying burden, including its dependence on accurate incidence and severity measures, are considered in the following section on injury surveillance (Section 2.1.3).

2.1.2.5 Body Area, Tissue Type, and Diagnosis. Consistency in the classification of injuries by body location, tissue type, and specific pathology is essential to identify injury patterns within sports and enable comparisons across contexts (Rae & Orchard, 2007). To support this, several diagnostic coding systems have been developed for surveillance, most notably the Sport Medicine Diagnostic Coding System (SMDCS) (Meeuwisse & Wiley, 2007) and the Orchard coding framework. The latter was originally introduced in the early 1990s as the Orchard Sports Injury Classification System (OSICS) and has undergone multiple revisions over time. In its most recent iterations, the system has expanded beyond injury diagnoses to include illness classifications and is now formally termed the Orchard Sports Injury and Illness Classification System (OSIICS) (Orchard & Genovesi, 2022; Orchard et al., 2024). In this thesis, the term OSIICS is used when referring to versions 14 and above. The current version maintains the established hierarchical four-character alphanumeric structure (first character: anatomical location; second: tissue or pathology; third and fourth: specific diagnosis), while providing enhanced diagnostic detail across areas such as concussion, mental health, and systemic conditions (Orchard et al., 2024). This expanded scope improves the consistency, precision, and comparability of surveillance data, supporting more detailed sport-specific analyses and long-term monitoring of injury and illness trends.

The most recent IOC consensus statement (Bahr et al., 2020), consolidated earlier statements, providing specific categories for reporting the body regions, areas, tissue types and pathologies. They highlighted that, while OSIICS and SMDCS provide detailed diagnostic specificity, they can be complex and inconsistently applied across sports. As a pragmatic solution, the IOC advises that all surveillance studies classify injuries at a minimum by body area and tissue type using agreed core categories, with OSIICS or SMDCS systems applied as optional extensions where more detailed diagnoses are required. Importantly, Bahr et al. (2020) emphasise that detailed diagnosis remains valuable for distinguishing between subtypes and identifying nuanced injury patterns, provided adequate expertise is available. This two-tiered approach balances feasibility and comparability with the capacity for sport-specific depth.

2.1.3 Injury Surveillance

Injury surveillance constitutes the descriptive component of sports injury epidemiology, aligning with Step 1 of van Mechelen’s (1992) prevention model: establishing the extent of the injury problem. Surveillance systems involve the systematic, ongoing collection, analysis, and interpretation of health-related information (Ekegren et al., 2016; Finch, 2006). Within sport, these systems monitor both the frequency and characteristics of injuries, supporting athlete monitoring, recognising injury trends, and identifying potential emerging problems. Importantly, surveillance provides the foundation for evidence-based decision-making, allowing for the evaluation of rule changes, training programmes, and medical interventions. Their accuracy and utility depend on the application of consistent injury definitions and classifications, as outlined in Section 2.1.1, which ensure cases are appropriately identified, categorised, and comparable across settings (Bahr et al., 2020; Fuller et al., 2006; Moore et al., 2023; Walden et al., 2023). Without standardised surveillance, data risk being unreliable, limiting the ability to compare findings across sports and populations. Robust surveillance systems providing clear definitions, accurate data collection and appropriate analysis methods are therefore critical to determine the high-quality evidence required to underpin effective injury prevention strategies. However, review evidence suggests the use of systematic, ongoing surveillance systems remains inconsistent across sporting contexts. Although more common in professional and elite sport, surveillance systems show wide variation in uptake across sports, with limited evidence on the quality of data produced (Costello et al., 2024; Ekergen et al., 2016).

To generate meaningful insights into athlete injuries, surveillance systems rely on a core set of epidemiological metrics. Consistent reporting of these measures provides essential context, enabling researchers to quantify the extent of injury problems and compare findings across sports (Hespanhol et al., 2015). Historically, the term risk has often been used more broadly to describe the likelihood of injury. However, the IOC consensus (Bahr et al., 2020), reinforced by subsequent sport-specific statements (Walden et al., 2023; Moore et al., 2023), clarifies that in epidemiology, risk refers to the proportion of athletes who sustain an injury during a specified period, whereas rates describe the frequency of injuries relative to athlete exposure time. Variations in usage of these terms have limited the interpretation and comparability of data. Consensus statements now provide clear guidance for the collection and interpretation of surveillance data (Bahr et al., 2020; Walden et al., 2023). These metrics begin with defining the population at risk and accurately quantifying athlete exposure, which together provide the denominators for injury rate calculations. Building on this foundation, incidence, prevalence, severity, and burden represent the core measures used to describe the occurrence and impact of injuries in sport. The following subsections outline each of these components in turn.

2.1.3.1 Population at Risk and Athlete Exposure. The population at risk refers to all individuals eligible to sustain an injury within a given sport and provides the denominator for risk and rate calculations (Hespanhol et al., 2015). However, there is some variation in how this population is defined. For example, in multi-sport tournament settings, Junge et al. (2008) proposed that all registered athletes should be considered part of the population at risk, regardless of whether they participate in competition. Others argue that only those who actually take the field of play should be included, as this better reflects true exposure to injury risk. While this concept remains important for clarity and comparability, recent guidance places greater emphasis on the accurate measurement of athlete exposure, which provides a more informative denominator for injury rate calculations (Bahr et al., 2020; Walden et al., 2023).

Within a population, an athlete's injury risk will vary according to the amount of time they are exposed to injury. Exposure therefore represents the total amount of time an athlete is at risk of sustaining an injury (Hopkins et al., 2007). Ideally, exposure is measured at the individual level, recording both match and training hours independently, which offers the most precise basis for incidence calculations (Fuller et al., 2006; Hägglund et al., 2005). In the consensus statements, match exposure is defined as time spent in competitive play between teams, while training exposure refers to structured team or individual activities aimed at maintaining or improving skills or physical conditioning under coaching supervision (Fuller et al., 2006). More recent recommendations further suggest subcategorising training into specific modalities, such as conditioning, warm-up, or rehabilitation, to provide a more detailed understanding of the contexts in which injuries occur (Bahr et al., 2020). Although individual exposure recording is most effective it is resource-intensive and may be impractical in many surveillance settings. As a more feasible alternative, consensus statements endorse team-based estimates, where match exposure is calculated as the product of matches played, number of athletes, and match duration, and training exposure as the product of sessions, athletes, and session duration (Fuller et al., 2006; King et al., 2009). While more practical, this approach is less accurate than individual-level data and limits the application of more advanced statistical models to examine risk factors (Bahr et al., 2020; Hägglund et al., 2005). The method selected should therefore balance feasibility with the research objectives, with individual-level exposure remaining the gold standard wherever possible.

2.1.3.2 Injury Prevalence, Incidence and Burden. Injury prevalence refers to the proportion of athletes affected by injury during a specified period and is calculated by dividing the number of injured athletes by the total number of athletes at risk. Prevalence can be reported at a single point in time (point prevalence) or across a defined interval such as a season (period prevalence) (Bahr, 2009; Clarsen et al., 2013; Clarsen et al., 2020) and is particularly valuable for capturing gradual-onset conditions, such as overuse injuries, where symptoms may fluctuate and no clear onset can be identified (Bahr, 2009; Clarsen et al., 2013; Mountjoy et al., 2016; Timpka et al., 2014). By reflecting the ongoing effect of injury at a population level, prevalence provides important insights into the sustained impact of sport participation, which may be underestimated if only incidence is reported. In contrast, incidence is more representative of sudden-onset or acute conditions. Injury incidence is a rate describing the number of new injuries within a defined population at risk over a specified time frame (Phillips, 2000). Multiple measures have been applied in the literature, including injury risk, injury rate, odds of injury, injury hazard, and mean time to injury. Consensus statements, however, agree that the most robust measure is the incidence rate, which adjusts for differences in athlete exposure. This is typically expressed as the number of new injuries per 1000 hours of athlete exposure, providing a standardised approach to compare across populations and sports (Bahr et al., 2020; Fuller et al., 2006; Hägglund et al., 2005; Junge et al., 2008; King et al., 2009; Mountjoy et al., 2016; Pluim et al., 2009; Timpka et al., 2014; Walden et al., 2023). Reporting incidence separately for match and training exposures is also recommended to reflect the distinct risk profiles of these contexts, as combined measures may obscure meaningful differences in injury patterns (Brooks & Fuller, 2006; Fuller et al., 2006). This classification allows the subsequent calculation of injury incidence in relation to different activities, aiding the assessment of injury risk factors.

While prevalence and incidence quantify the likelihood of injury, they do not capture the consequences of injury for athletes or teams. The concept of injury burden (previously defined in Section 2.1.2.4) has been introduced to address this by combining both frequency (incidence or prevalence) and severity, providing a more comprehensive measure of the injury impact (Bahr et al., 2018). Severity is most often defined as time lost from training or competition, but may also include reduced performance, medical costs, or diminished quality of life. As such, burden reflects both the likelihood and the consequences of injury, which can be represented visually as a risk matrix (Bahr et al., 2018), ultimately providing more accurate information for developing prevention strategies. Despite its importance, the injury burden remains inconsistently reported in the sports injury literature, with many studies continuing to focus on incidence alone. This limits the ability to prioritise prevention efforts according to the injuries that matter most. Hence, the most recent consensus statements recommend that injury burden be routinely reported alongside incidence and prevalence, ensuring that surveillance data reflect both the likelihood and the consequences of sports injuries (Bahr et al., 2020; Moore et al., 2023; Walden et al., 2023). Adopting this approach is critical to presenting a comprehensive picture of the injury problem and aligning sports injury epidemiology with broader healthcare practices.

2.1.3.3 Data Collection and Reporting Methods. The quality and utility of injury surveillance research depend heavily on the methods used for data collection and reporting. Data collection approaches must be tailored to the demands of the specific sport, ensuring that the context of training, match play, and other relevant exposures is accurately captured. Important considerations include who is responsible for collecting the data (e.g., medical staff, coaches, researchers, or self-reported by athletes), the sources of data (such as medical records, injury report forms, or electronic monitoring systems), and the frequency, timing, and duration of data collection (Bahr et al., 2020; Walden et al., 2023). These factors directly influence the completeness, accuracy, and feasibility of sustained surveillance in applied sport settings (Ekegren et al., 2016). Assessing and reporting the quality of recorded data is equally important to uphold surveillance standards. Core indicators include validity (capturing the true nature of the injury problem), completeness (ensuring all relevant injuries are recorded), and reliability (consistency across recorders, time periods, and settings) (Bahr et al., 2020; Clarsen et al., 2021). Yet, Ekegren et al.'s (2016) review found that many surveillance studies failed to evaluate or report data quality, limiting confidence in their findings. Systematic assessment of these indicators is therefore essential, not only to strengthen the credibility of results but also to identify weaknesses in data collection processes. In turn, this highlights the need for education, training, and support for data collectors.

Finally, the consistent and transparent reporting of surveillance findings is vital. Without clear and comparable presentation of results, the utility of high-quality data is diminished. To achieve this, general epidemiological reporting guidelines such as STROBE (von Elm et al., 2007) and sport-related consensus statements (e.g., Fuller et al., 2006; Bahr et al., 2020; Walden et al., 2023; Moore et al., 2023) provide structured frameworks for reporting study design, data collection, and outcomes. Adherence to these standards improves comparability across studies and strengthens the evidence base needed to inform prevention strategies.

2.1.3.4 Challenges in Implementation. Despite consensus guidelines and advances in methodology, injury surveillance in many sports remains inconsistent and incomplete. Few have established truly systematic, ongoing systems, with surveillance often fragmented or absent outside elite professional contexts (Costello et al., 2024; Ekegren et al., 2016). Practical barriers such as limited medical resources, insufficient staff training, and underreporting of gradual-onset injuries further undermine data quality and comparability (Clarsen et al., 2013; Timpka et al., 2014). Even where systems exist, sustaining compliance requires balancing methodological rigour with feasibility, minimising burden on medical teams while capturing detailed, accurate information (Bahr et al., 2020). As a result, high-quality surveillance remains the exception rather than the norm, restricting the development of robust, sport-specific evidence bases (Costello et al., 2024; Moore et al., 2023). Implementing a systematic surveillance system to generate reliable and comparable data therefore forms an important focus of the present thesis. Addressing these issues requires effective collaboration between researchers, clinicians, and governing bodies to fully embed surveillance into routine sporting structures. These challenges are considered further in Section 2.2.2, which examines injury epidemiology in netball.

2.1.4 Frameworks and Methods for Understanding Injury Aetiology and Causation

Having established how injury surveillance describes the extent of the problem, the next step in the prevention process is to understand why injuries occur. This aligns with Step 2 of van Mechelen's (1992) model and subsequent adaptations, which emphasise identifying the aetiology and causation of injury as the foundation for prevention. Within the sports injury literature, the terms aetiology and causation are often used interchangeably, although subtle distinctions exist. Aetiology refers broadly to the study of factors that contribute to the origin and development of injury, including intrinsic and extrinsic risk factors that influence an athlete's susceptibility. Causation, in contrast, refers to the process by which this susceptibility is translated into injury, most critically through a specific injury-inciting event (Bahr & Krosshaug, 2005; Meeuwisse, 1994). In this thesis, injury aetiology refers to the intrinsic and extrinsic risk factors that influence an athlete's susceptibility to injury, while causation refers to the process by which this susceptibility is translated into injury through a specific inciting event. While these elements are inherently interrelated, a range of theoretical models have been developed to explain their interaction. The following sections review these models, with a specific focus on methodological approaches for examining injury-inciting events.

2.1.4.1 Terminology and Definition of Injury Mechanisms. A critical first step in advancing the analysis of injury causation is ensuring clarity and consistency in terminology. In injury surveillance, injuries are typically classified using broad descriptors such as mode of onset (acute/overuse) and mechanism of onset (contact/non-contact), which provide an initial, surveillance-level description of how injuries occur (see Section 2.1.2.1). To inform targeted prevention strategies, greater sport-specific detail is required to capture the complexity of how injuries occur. However, the term injury mechanism has been used inconsistently in the literature, sometimes referring to these broad onset descriptors and, in other cases, referring to detailed biomechanical processes or sport-specific movement patterns (Bahr & Krosshaug, 2005). Bahr and Krosshaug (2005) proposed the term injury-inciting event to describe the specific event in which injury occurs and recommended that injury mechanisms should be conceptualised within this event. In this context, injury mechanisms refer to the situational, behavioural and biomechanical processes operating during the inciting event that ultimately produce tissue failure. They suggested that a complete description should include four levels: (1) sport-specific playing situation (e.g., position, time in match, court location), (2) athlete and opponent behaviour immediately preceding injury, (3) gross biomechanical characteristics (whole-body kinematics), and (4) detailed joint or tissue biomechanics. Together, these levels provide a comprehensive description of how injury occurs and form the conceptual basis for the methodological approach adopted in this thesis. Accordingly, in this thesis, mechanism of onset is used to refer to surveillance-level classifications (e.g., contact/non-contact), whereas the term injury-inciting event is used when referring to the detailed situational, behavioural, and biomechanical processes underpinning injury causation.

2.1.4.2 Theoretical Models of Injury Aetiology and Causation. Historically, sports injury aetiology research adopted reductionist approaches, examining the influence of single risk factors in isolation. While these studies provided some useful insights, they offered only a partial understanding of why injuries occur and limited progress toward prevention (Bahr & Krosshaug, 2005; Quatman et al., 2009). Recognising that injuries rarely result from a single cause, theoretical models were developed to explain how multiple risk factors interact with inciting events to produce injury. A key early contribution was Meeuwisse's (1994) multifactorial model, adapted from infectious disease frameworks, which provided the first structured attempt to link predisposing factors with the causal pathways through which injury manifests. The model distinguished between intrinsic factors (internal to the athlete), including non-modifiable (e.g., sex, age, previous injury) and modifiable characteristics (e.g., strength, balance, flexibility), and extrinsic factors (environmental), such as playing surface, footwear, sport rules, protective equipment, and opponent behaviour. While these factors determine susceptibility, they are rarely sufficient on their own. Injury occurs only when a specific inciting event generates biomechanical loads that exceed tissue tolerance (e.g., ankle inversion following an awkward landing). The strength of Meeuwisse model lay in its recognition that injury risk arises from the interplay of multiple factors rather than isolated causes. By emphasising the importance of distinguishing between interactions and confounding factors, it established the need for multivariate approaches to advance injury prediction and understanding.

Building on Meeuwisse's original framework, Bahr and Krosshaug (2005) expanded injury causation models by providing a more detailed conceptualisation of the inciting event within a multifactorial context (Figure 2.2). By explicitly linking contextual, behavioural, and biomechanical components, their model strengthened the integration of injury-inciting analysis within broader causation frameworks and clarified how specific events translate susceptibility into injury. However, Gissane et al. (2001) criticised early injury models for framing injury as a linear process and failing to account for post-injury outcomes and ongoing participation. In response to this critique, Meeuwisse et al. (2007) proposed a dynamic, recursive model of injury aetiology (Figure 2.3), in which sports participation itself may induce persistent adaptations in injury susceptibility, even in the absence of injury. Within this model, the same inciting event may result in injury or physiological adaptation, with post-injury outcomes further modifying future risk through return to sport or cessation of participation.

While Meeuwisse et al.'s (2007) recursive model provided a more dynamic reflection of the sports injury process, Windt and Gabbett (2017) argued it overlooked athlete workload, a factor strongly associated with injury risk in elite sport (Cross et al., 2016; Hulin et al., 2014, 2016). Defined as the cumulative demands of training and competition over time (Gabbett et al., 2014), workload is essential for promoting adaptation and peak performance but, if excessive, can induce fatigue and maladaptation (Halson, 2014). It is typically quantified using external measures of total work (e.g., duration, distance, frequency, actions performed) and internal measures of physiological or perceptual stress (e.g., heart rate,

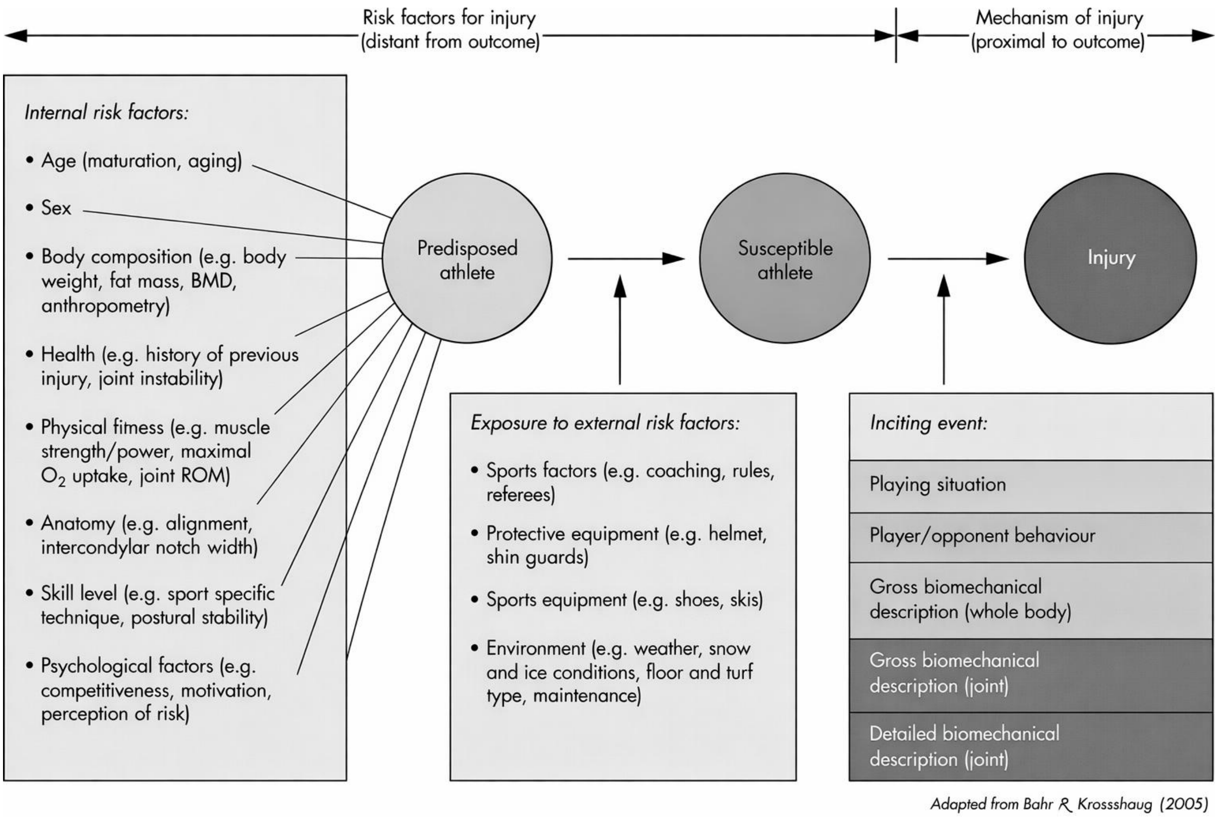

Figure 2.2 *A comprehensive, multifactorial model of sports injury aetiology, developed from the original Meeuwisse* (1994) *model by* Bahr & Krosshaug (2005)

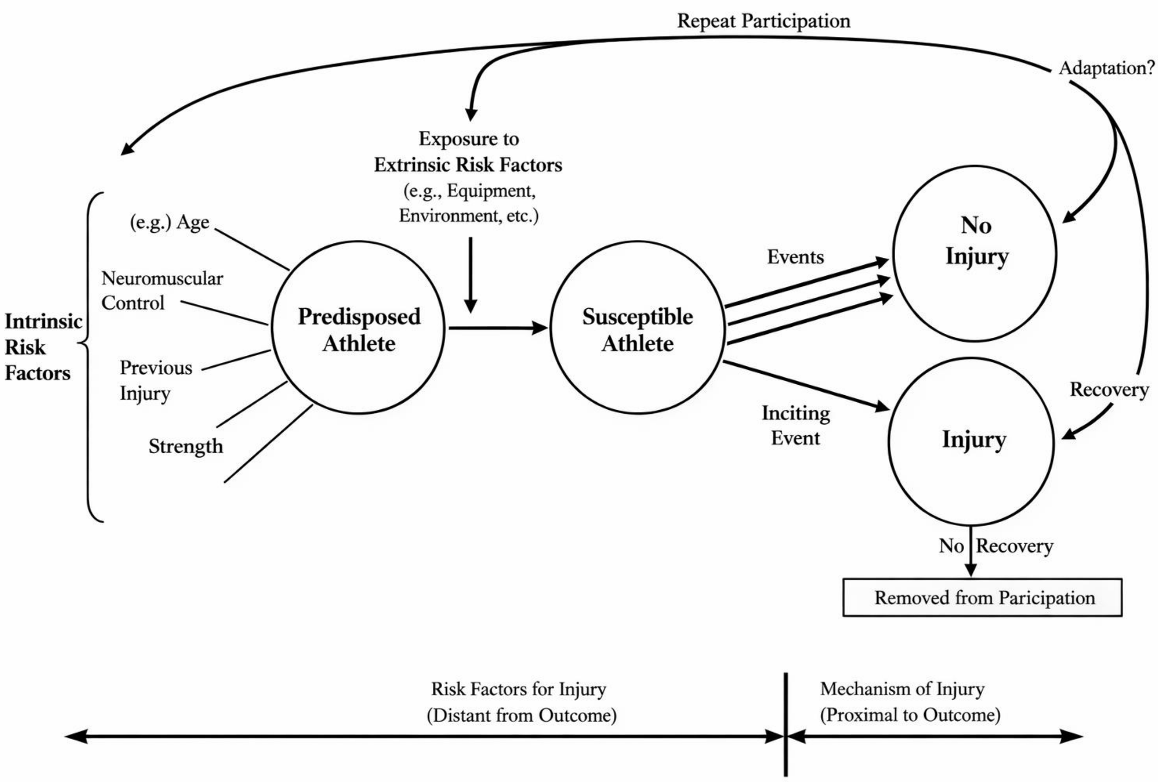

Figure 2.3 *Dynamic, recursive model of aetiology in sports injury* (Meeuwisse et al., 2007)

blood lactate, rating of perceived exertion). Recognising that these dimensions were not captured by earlier models, Windt and Gabbett (2017) proposed the workload–injury aetiology model (Figure 2.4). This framework positioned workload not as a risk factor or inciting event, but as the “vehicle” moving an athlete from a predisposed to a susceptible state. Workload itself does not directly cause injury but modifies risk by shaping susceptibility to extrinsic factors and inciting events. Adaptations may therefore be positive, reducing injury risk through improved fitness, or negative, increasing risk through fatigue. Consistent with the Meeuwisse et al. (2007) model, injury risk is viewed as constantly evolving, with subsequent injury, rehabilitation, and return-to-play processes further modifying future risk.

The earlier models emphasised the limitations of reductionist approaches and the importance of risk factor interactions, but they retained a structured framework linking intrinsic, extrinsic, and situational factors with inciting events. In contrast, Bittencourt et al. (2016) proposed a complex systems approach (Figure 2.5), adapted from health and disease epidemiology, which conceptualises injury as an emergent outcome of a dynamic web of interacting determinants. Rather than focusing on isolated risk factors, the model emphasises the patterns of interaction that shape an athlete’s evolving risk profile, marking a shift from multifactorial frameworks toward a systems-based perspective on sports injury aetiology. Within their model, injuries emerge from a web of determinants that differ in both

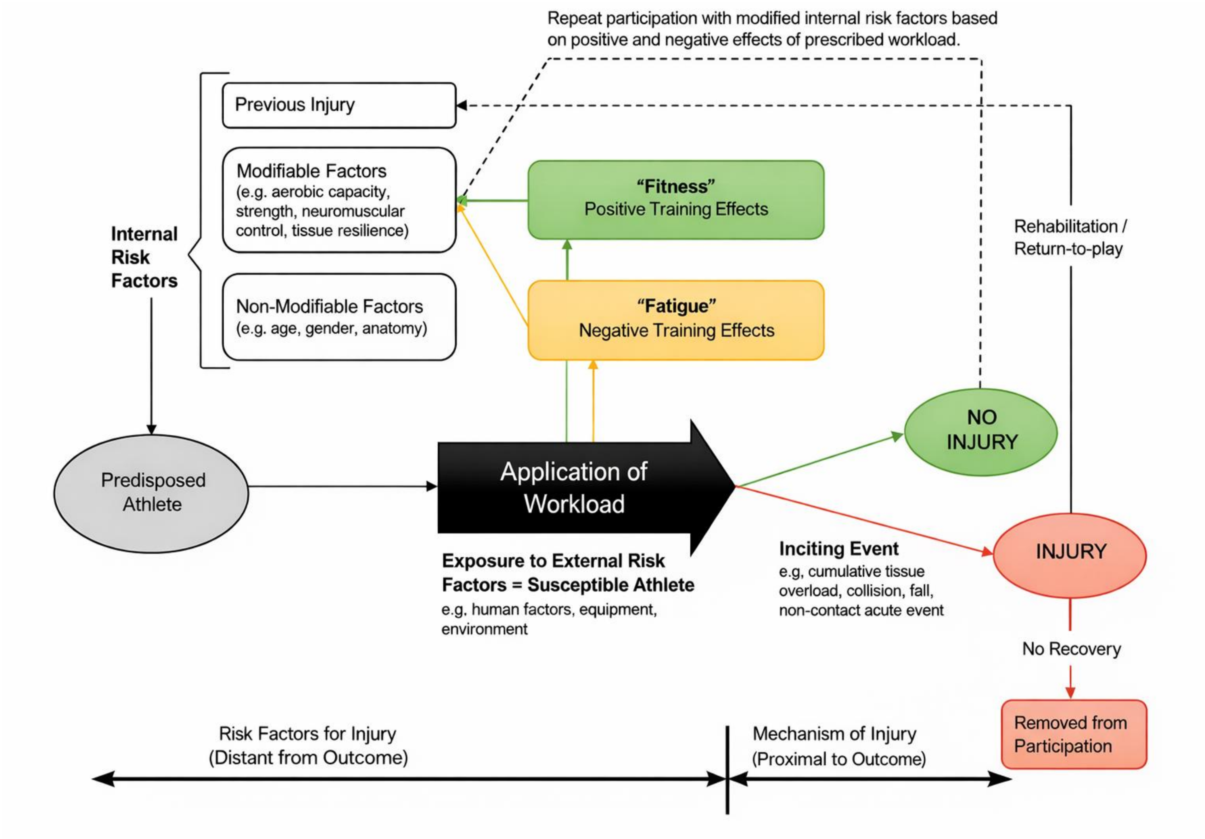

Figure 2.4 *Workload-injury aetiology model* (Windt & Gabbett., 2017)

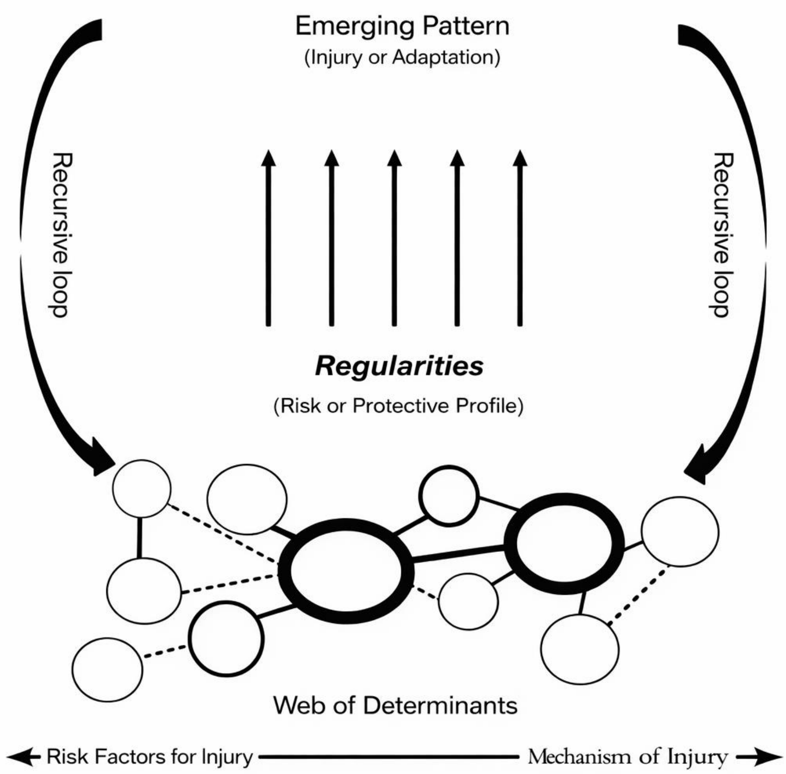

Figure 2.5 *Complex model for sports injury* (Bittencourt et al., 2016)strength and

connectivity, with highly connected determinants exerting greater influence on outcomes (illustrated as darker circles, with thick lines for strong interactions and dotted lines for weak ones). The resulting risk profile determines the likelihood of injury, but its effect is contingent on the inciting event. The same biomechanical event (e.g., an ankle inversion) may cause injury in one athlete but prompt adaptation in another. Thus, injury occurrence is understood not as the result of a fixed trigger, but as an emergent outcome of the determinant network interacting with the inciting event. By focusing on profiles rather than single causes, the model calls for research to identify patterns of interaction to more accurately capture the complexity of sports injury causation.

Together, these models illustrate the shift from linear, reductionist perspectives to dynamic, multifactorial, and systems-based understandings of sports injury causation. While each framework varies in how it positions the inciting event, all recognise that injury cannot be explained by risk factors alone. It is the injury-inciting event, including the situational, behavioural and biomechanical processes operating within it, that ultimately determines whether susceptibility translates into injury. Despite recent growth in research examining injury-inciting events, systematic and standardised analysis remains limited in many sports and is therefore an important component of the present thesis.

2.1.4.3 Assessment of the Injury Inciting Event. Across all theoretical models of injury causation, the inciting event is consistently emphasised as central to understanding how injuries occur (Bahr & Krosshaug, 2005; Meeuwisse, 1994; Meeuwisse et al., 2007). As previously outlined, while risk factors establish an athlete's susceptibility, the injury-inciting event comprises the situational, behavioural and biomechanical processes that transform susceptibility into injury (Krosshaug et al., 2005). Accurate identification of injury-inciting events therefore enables researchers and clinicians to move beyond associations toward causal explanations, providing the foundation for targeted prevention strategies (Bahr & Krosshaug, 2005). For example, recognising that acute ankle sprains often involve inversion and internal rotation when landing on another player's foot (Bagehorn et al., 2024) can inform specific neuromuscular training, proprioceptive drills, footwear adjustments, and bracing strategies.

Despite its recognised importance, early research on inciting events was narrow in scope. Surveillance studies typically relied on athlete or medical staff reports, using inconsistent terminology and retrospective recall. This introduced bias and often yielded data that were overly simplistic and unreliable (Krosshaug et al., 2005; Timpka et al., 2014). Moreover, such approaches rarely provided a comprehensive account of the playing situation, player/opponent interactions and associated whole-body or joint biomechanics, required for a full understanding of injury causation (Bahr & Krosshaug, 2005). In recent years, however, there has been a substantial increase in studies investigating inciting events, driven largely by advances in video-based methods. The widespread filming of elite competitions has enabled systematic examination of injury events particularly at this level, providing richer insights into the situational and behavioural context alongside qualitative biomechanical features (Bahr & Krosshaug, 2005). This body of research marks a significant step forward, yet challenges remain, particularly in achieving standardisation of classification frameworks, ensuring inter-rater reliability, and validating biomechanical inferences drawn from video.

A precise description of injury situations in complex team sports is a challenging process. Bahr & Krosshaug (2005) emphasised the need for sport-specific descriptions of the events leading to injury, using clear definitions, terminology, and systematic methods of analysis to ensure valid and comparable findings across studies. One of the first structured frameworks was the Football Incident Analysis (FIA), developed by Andersen et al. (2003). Adapted from performance analysis methods, the FIA combined video footage with medical records to code 19 categories describing injury events, including the injured player, team/opponent actions, match context, playing situation, and foul play. Compared with traditional surveillance methods, this approach enabled more detailed situational descriptions and has been applied to identify common inciting events in football (Andersen et al., 2004; Arnason et al., 2004). More recently, the FIA has been critiqued for oversimplifying complex, dynamic injury situations and for offering limited flexibility to capture multifactorial interactions (Aiello et al., 2023). Nonetheless, it provided the foundation for a wide range of video-based frameworks that have since been developed and applied in sports such as cricket, rugby, ice hockey, basketball, lacrosse and handball (Gupta et al., 2020; Hendricks et al., 2016; Hutchison et al., 2015; Krosshaug et al., 2007b; Lincoln et al., 2013; Olsen et al., 2004). These frameworks generally follow the same principle: combining situational descriptors (e.g., phase of play, opponent involvement) with qualitative or semi-quantitative biomechanical assessment. This research has demonstrated considerable value in advancing understanding of how injuries occur, revealing some consistent biomechanical mechanisms across sports, such as valgus collapse during non-contact ACL injuries, while also highlighting sport-specific situational triggers (Krosshaug et al., 2007b; Olsen et al., 2004; Waldén et al., 2015). However, most frameworks remain focused on specific injury types, particularly ACL injuries and concussions, and show considerable variation in classifications and terminology within and across sports.

2.1.4.4 Limitations and Challenges in Inciting Event Assessment. While video-based frameworks have advanced the analysis of inciting events, most attempts to capture biomechanical detail still rely on qualitative visual inspection. This approach, although valuable for describing whole-body patterns, has recognised limitations in its capacity to accurately estimate joint kinematics or tissue loading and can be influenced by rater expertise (Krosshaug et al., 2005). More advanced laboratory-based methods, such as model-based image matching (MBIM) originally developed by Krosshaug and Bahr (2005), can generate precise biomechanical estimates but require high-quality footage from multiple synchronized cameras and substantial computational resources, making them impractical in many applied sporting contexts. Consequently, qualitative video frameworks remain the dominant approach. However, the lack of standardisation across systems undermines comparability and restricts the translation of findings into effective prevention strategies. Varied classification systems can therefore produce inconsistent findings, increasing the risk of developing and implementing ineffective interventions (Aiello et al., 2023). In response, broader video analysis frameworks are beginning to emerge to standardise sport-specific terminology, such as the Rugby Union Video Analysis framework of descriptors and definitions (Hendricks et al., 2020), which aims to reduce bias, enhance reliability, and ensure greater consistency across studies.

Overall, video-based frameworks have advanced the assessment of injury-inciting events by moving the analysis beyond retrospective reports, offering richer insights into how injuries occur in real-world competition. However, their effectiveness depends on the availability of high-quality footage. Studies in football show that only around half of reported injuries can be identified on video, with single-camera views and poor image quality further limiting analysis (Andersen et al., 2004; Arnason et al., 2004; Krosshaug & Bahr, 2005). Gradual-onset injuries, or those without immediate disability are also often missed, and most training injuries remain uncaptured due to a lack of recordings. Despite these limitations, video remains the most accurate method currently available for assessing injury-inciting events in competition. Its value, however, is maximised when combined with medical diagnoses to ensure correct injury identification and with athlete or clinician reports to provide contextual detail (Krosshaug et al., 2005). Addressing these challenges requires the development of consistent, sport-specific classification systems to maximise comparability, reliability, and the translation of findings into effective prevention strategies.

2.2 The Injury Problem in Netball

To clearly understand the extent, aetiology and causation of injuries in netball, it is essential to consider not only the available evidence but also its quality and consistency. This section presents the findings to date from netball injury research, focusing first on the physical demands of the game, before outlining what is known about the epidemiology of injuries, including their incidence, location, type, severity, and contextual characteristics. It then considers research on how injuries occur, including injury onset descriptors (e.g., mechanism of onset classifications such as contact/non-contact, and basic activity at injury onset) and injury-inciting events, before identifying the key gaps and limitations that constrain current understanding. Together, this provides a foundation for the subsequent studies in this thesis, which aim to strengthen the evidence base available to support injury prevention in elite UK netball.

2.2.1 Physical Demands of Netball

Netball is a fast, dynamic, and highly competitive team sport that places substantial physical and biomechanical demands on players, shaped by its rules, positional roles, and restricted playing areas. Early time–motion analyses described its intermittent structure, with frequent changes between high- and low-intensity activity occurring every one to four seconds (Davidson & Trewartha, 2008; Otago, 1983; Steele & Chad, 1991; Woolford & Angove, 1991, 1992). Subsequent notational studies, such as Fox et al. (2013), confirmed these intermittent demands in elite match-play, using updated video-based methods. More recently, the application of global positioning systems (GPS), heart rate monitoring, and accelerometers has extended this work by providing detailed quantification of positional workloads (Bailey et al., 2017; Mackay et al., 2025; van Gogh et al., 2017). These data show substantial variation across the seven playing positions. Centres, who link attack and defence, typically cover the greatest distance per match (up to 8 km) and record the highest cardiovascular and accelerometer loads, whereas goal shooters and goal keepers, largely restricted to the shooting circle, cover considerably less ground (~4 km) with lower overall outputs (Bailey et al., 2017; Davidson & Trewartha, 2008). Wing and goal attack/defence positions fall between these extremes, reflecting their tactical roles and allocated court zones (Brooks et al., 2020a; Young et al., 2016).

Despite these positional differences, all players perform fundamental movement patterns, including repeated accelerations and decelerations, rapid directional changes, vertical jumps, one-legged landings, and ball handling under defensive pressure (Fox et al., 2013; Thomas et al., 2017). These actions occur repeatedly across a standard 60-minute match and place continuous demands on both anaerobic and aerobic energy systems. Additionally, netball's unique footwork rule adds considerably to the mechanical loading during these common activities. The rule requires players to halt within 1.5 steps of receiving the ball, often following a jump or high-speed movement, creating substantial deceleration forces. Biomechanical studies report vertical ground reaction forces of 2.4–5.7 body weights and horizontal forces of 2.0–4.6 body weights under landing conditions specific to netball (Otago, 2004; Steele, 1990). Elite players are reported to perform around 58 landings per match, with approximately 65% on one leg (Hopper et al., 1992). In addition, many of these landings occur while contested by an opponent or after mid-air turns, further elevating joint loading and instability risk (Stuelcken et al., 2013). Although netball is formally classified as a non-contact sport, physical contest is common, particularly in defensive play. Collectively, these characteristics highlight the high physical demands of the sport with frequent exposure to high workloads and intense mechanical loading, particularly during landings and direction changes. These unique demands underpin the sport's reputation for a high risk of injury (Downs et al., 2021; Whitehead et al., 2021).

2.2.2 Injury Epidemiology in Netball

Netball has long been recognised as a sport with a high risk of injury, particularly affecting the lower limb. Accordingly, more than 60 studies, spanning nearly 40 years, have examined the epidemiology of netball injury, reflecting a considerable body of published work. However, two recent reviews, one evaluating the netball injury evidence (Downs et al., 2021) and one broader synthesis of applied sports science (Whitehead et al., 2021), highlight that this literature is highly fragmented, with inconsistent methodologies and a paucity of high-quality studies at the elite level. The majority of netball injury research is descriptive, quantifying the incidence, type, severity and burden of injuries across different populations and levels of play. Fewer studies have employed an analytic epidemiological design, which seeks to explain why injuries occur by examining associations between risk factors and injury outcomes, and/or by exploring injury onset descriptors (Whitehead et al., 2021). More recently, research has also started to examine injury-inciting events in greater detail, using video-based methods to capture the situational and biomechanical sequences that contribute to injury. While methodologically distinct, both analytic epidemiology and injury-inciting event analysis contribute to Step 2 of injury prevention models, which focuses on understanding injury aetiology and causation. Together, they extend knowledge beyond descriptive surveillance (Step 1) by providing insight into the circumstances and processes through which injuries occur.

Despite these developments, the evidence base remains uneven, with limited application in elite cohorts and minimal injury research to date conducted in the UK. This highlights the need for more robust, standardised approaches to strengthen the comparability and utility of findings. The following sections therefore review the current evidence from descriptive and analytic netball injury research, summarising injury incidence, type, severity and burden, and synthesising what is known about how injuries occur (including injury onset descriptors and injury-inciting events). Key gaps and limitations in the current evidence base are highlighted throughout. A detailed review of risk factor assessment lies beyond the scope of this thesis.

2.2.2.1 Injury Incidence. Research has attempted to quantify netball injuries using a variety of data sources, including hospital and insurance data, as well as competition-based surveillance. Early studies based on hospital and insurance records reported hospitalisation rates of 89–143 per 100,000 participants per year (Hume, 1993; Hume & Marshall, 1994), with netball accounting for between 6–7% of all sports-related emergency presentations (Cassell et al., 2003; Finch, 1998). Subsequent insurance-based reports have expressed incidence as 1.4–9.5 injuries per 1000 players (Flood & Harrison, 2009; Otago & Peake, 2007). While valuable for estimating more serious injuries requiring medical care or claims, these figures substantially underestimate overall incidence because they do not capture less severe injuries.

Competition-based surveillance has provided broader estimates, including injuries of lesser severity. Early studies typically reported only counts of injuries sustained during tournaments (Hopper, 1986; Hopper & Elliott, 1993; Purdam, 1987), whereas later investigations calculated rates relative to exposure. Across adult community and sub-elite cohorts, prospective studies have typically reported between 11.3 and 23.8 injuries per 1000 player-hours (Finch et al., 2002; Hume & Steele, 2000). At the elite level, higher rates have been reported, with Langeveld et al. (2012) reporting 500.7 injuries per 1000 hours when exposure was measured as individual player match time to injury. More recently, Janse van Rensburg et al. (2021) reported an incidence of 54.8 injuries per 1000 hours during the 2019 Netball World Cup, while surveillance in the Australian Suncorp Super Netball league identified 3.9 injuries per 365 player contract days (Toohey et al., 2022). These values exceed those reported in other elite female team sports, such as football (6.1 per 1000 hours; López-Valenciano et al., 2021) and basketball (24.9 per 1000 hours; Deitch et al., 2006), highlighting the high injury rates in netball. However, the wide variety of study designs and approaches to calculating incidence (e.g., per 1000 players, per 1000 hours, or per contract days) has produced considerable variation in reported rates. This inconsistency makes comparisons between studies challenging and limits the ability to apply the evidence with confidence.

2.2.2.2 Injury Location. Across all levels of play, netball injury research consistently identifies the lower limb as the most frequently affected region. Ankle injuries are most common, typically representing one-third to over three-quarters of all cases (Downs et al., 2021) and approximately 28% in the elite Suncorp Super Netball (Toohey et al., 2022). Where incidence has been expressed relative to exposure, ankle injury rates have ranged from 5.4 to 12.7 per 1000 player-hours in community and sub-elite cohorts (Finch et al., 2002; Hume & Steele, 2000), rising to 21.9 per 1000 hours at the elite 2019 World Cup (Janse van Rensburg et al., 2021). Knee injuries are less frequent overall, though still substantial, accounting for 8–50% of cases depending on the cohort (Downs et al, 2021; Toohey et al, 2022). Sub-elite cohorts report incidence between 1.5 and 2.4 per 1000 hours (Finch et al., 2002; Hume & Steele, 2000), while the elite cohort at the World Cup recorded

8.0 per 1000 hours (Janse van Rensburg et al., 2021). Other injury sites are less common but remain clinically important. Hand, wrist, and finger injuries typically account for 5–20% of all cases (Downs et al., 2021), with the World Cup data indicating incidence of 5.4 per 1000 player-hours, approximately 10% of all injuries (Janse van Rensburg et al., 2021). Shoulder injuries usually represent 5–7% of reported cases (McManus et al., 2006; Smyth et al., 2020), with an elite incidence of 3.3 per 1000 player-hours (Janse van Rensburg et al., 2021). Lower back injuries are also noted, ranging from 3% to 18% across studies (Downs et al., 2021; Ellapen et al., 2015; McKay et al., 1996), with elite-level estimates of 4.0 per 1000 player-hours (Janse van Rensburg et al., 2021).

2.2.2.3 Injury Type and Pathology. In terms of tissue type and pathology, ligament sprains dominate the netball injury profile (Downs et al., 2021), with lateral ankle ligament injuries consistently the most common diagnosis across levels of play. Older studies reported ankle ligament sprains accounting for 38–67% of all injuries (Hopper & Elliott, 1993; Hume & Steele, 2000; Langeveld et al., 2012; McKay et al., 1996; McManus et al., 2006; Singh et al., 2013), and more recent datasets confirm their predominance at the elite level, with ankle ligament sprain the most frequent diagnosis at the 2019 Netball World Cup (Janse van Rensburg et al., 2021) and in the Suncorp Super Netball surveillance (Toohey et al., 2022). Knee ligament injuries are less frequent but remain important, including medial collateral (2–9%), lateral collateral (1–6%), and anterior cruciate ligament (0.6–9%) disruptions (Hopper et al., 1995a; Singh et al., 2013). Muscle strains, contusions, and abrasions are also common, with muscle injuries typically affecting the calf, hamstrings, and lumbar spine (McKay et al., 1996; McManus et al., 2006), while meniscal tears represent the most frequent intra-articular knee pathology (Hopper et al., 1995a; Langeveld et al., 2012). Fractures are less common but occur most often in the ankle/foot and hand/fingers (Singh et al., 2013). Concussion and head injuries, although less frequent than musculoskeletal pathologies, have become increasingly recognised in recent years. Historically under-reported, concussion accounted for the second most common diagnosis in a sub-elite cohort (Smyth et al., 2020) and was recorded at 2.0 per 1000 player-hours in the elite World Cup surveillance (Janse van Rensburg et al., 2021). This emerging evidence highlights the growing importance of monitoring head injury in netball alongside more established musculoskeletal concerns.

While most of these injuries are acute, overuse pathologies are also evident, particularly in the lower limb. Prospective studies in younger cohorts suggest that 15–20% of injuries are overuse, commonly involving shin pain, lumbar spine symptoms, and Achilles tendon complaints (Ellapen et al., 2015; McManus et al., 2006). Notably, Sinclair et al. (2020) reported a higher prevalence, with overuse injuries accounting for 46% of all cases in a combined age-group state-level cohort in South Africa. In one of the few studies to apply contemporary surveillance methods, Bissell and Lorentzos (2018) reported an overuse injury prevalence of 52.7% in a 12-week competitive season among sub-elite Australian players, with the ankle (26%) and knee (21.2%) the most commonly affected sites. Other sources suggest lower figures, with insurance-based datasets attributing 5–10% of claims to tendon-related conditions (Otago & Peake, 2007) and elite Suncorp Super Netball surveillance reporting tendon injuries, primarily Achilles and patellar tendinopathy, as 12% of all diagnoses (Toohey et al., 2022). These discrepancies highlight how overuse injuries may often be under-represented in competition-based surveillance, as they may not cause immediate time-loss or result from a single inciting event (Downs et al., 2021). Nevertheless, they contribute substantially to long-term morbidity and impaired performance, underscoring the importance of capturing both acute and overuse pathologies in netball injury research.

Subsequent injuries are less frequently reported in netball research, but available evidence indicates they form an important part of the injury profile (Downs et al., 2021; Whitehead et al., 2021; Smyth et al., 2020). Across studies, most injuries are classified as new; however, those that reoccur tend to be the injuries already most prevalent in the sport, particularly ankle sprains and knee injuries. For example, Langeveld et al. (2012) reported that 72% of injuries among elite South African players were new, with recurrent injuries most common at the ankle (49%), knee (21%), lower leg/Achilles (29%), and fingers (11%). Similarly, Hopper et al. (1995a) reported 20% recurrence at the knee and 35% at the ankle, while Singh et al. (2013) identified recurrent ankle and knee injuries in 24% of elite Jamaican players. More recently, Sinclair et al. (2020) found that almost a third of all were re-injuries, reinforcing the scale of the problem. Recurrent ankle sprains are a particular concern, as they are strongly linked to the development of chronic ankle instability (CAI). In a cohort study of netball players, Attenborough et al. (2016) reported that 47% had sustained a recurrent ankle injury, and of these, 64% experienced moderate-to-severe CAI symptoms. Despite these findings, the systematic investigation of subsequent injuries in netball remains limited.

2.2.2.4 Injury Severity and Burden. Although definitions of severity differ across studies, the majority of netball injuries are classified as minor or moderate, requiring limited treatment and only short time-loss from play (Downs et al., 2021). However, a smaller subset of injuries are severe, typically located at the lower limb, and are responsible for the greatest disruption to performance and participation. Among these, knee ligament injuries are consistently identified as the most serious. While ankle sprains are more frequent, they are usually mild-to-moderate in severity, resulting in far shorter absences, often less than 30 days, whereas knee injuries more often require referral to specialist care, surgical intervention, and prolonged rehabilitation (Downs et al., 2021; McKay et al., 1996; Singh et al., 2013). Anterior cruciate ligament (ACL) ruptures, though relatively uncommon, are of particular concern as they result in the greatest time-loss and incur the highest medical costs in netball (Janse van Rensburg et al., 2021; Otago, 2004;). Hospital and insurance datasets highlight this impact, with ACL ruptures reported as the most common diagnosis leading to hospital admission in Australia (16.5% of netball-related cases; Flood & Harrison, 2009) and netball ranked second only to rugby union as a contributor to ACL reconstructions in New Zealand (Gianotti et al., 2009). At the elite level, surveillance from the 2019 World Cup confirmed ACL rupture as the single most severe injury type, with an average time-loss of 271 days per case (Janse van Rensburg et al., 2021). Similarly, Suncorp Super Netball surveillance identified ACL injuries as the most severe, typically resulting in season-ending absence (Toohey et al., 2022).

Other severe injuries, though less frequent, include fractures of the ankle/foot and hand/fingers, Achilles tendon ruptures, and shoulder dislocations, all of which carry prolonged recovery times and functional limitations (Downs et al., 2021; Hume, 1993; Otago & Peake, 2007; Singh et al., 2013). Together, these findings outline the profile of the most severe injuries in netball however, to fully understand their impact, injury burden is a critical measure. As outlined in Section 2.2.1.2, burden reflects the combined effect of injury incidence and severity (typically expressed as days lost) and therefore captures both the likelihood and consequences of injury. To date, only surveillance from Suncorp Super Netball has reported burden metrics, identifying knee ligament injuries, particularly ACL ruptures, as the most burdensome due to their long absences despite lower incidence (Toohey et al., 2022). Beyond this, no consistent assessment of burden has been undertaken in netball across all levels, underscoring the need for further evaluation to provide a complete picture of the impact of injuries on athlete health and team performance.

2.2.2.5 Injury Characteristics. Beyond overall incidence, type, severity, and impact, descriptive epidemiology has examined contextual characteristics of netball injuries. These demonstrate that injury incidence is not uniform but varies according to exposure and playing context, providing important nuance to surveillance data. While primarily descriptive, this contextual information also begins to overlap with, and inform, the analyses required for Step 2 of the injury prevention process, as outlined in the models. Accordingly, examining variation across different contexts such as matches and training, playing positions, age groups, and playing levels adds depth to the epidemiological profile of netball injuries and helps identify patterns that may warrant closer investigation.

Few studies have reported injuries separately for matches and training, but those that do consistently show a higher proportion of injuries occurring in matches than in training. Langeveld et al. (2012) and Joseph et al. (2019) reported that over 90% of injuries occurred in matches, while Sinclair et al. (2020) identified 58% in matches, 29% during training and 13% in pre-season training. Franettovich Smith et al. (2020) is one of the few studies to report separate incidence rates in a community-club cohort, reporting 32.3 injuries per 1000 h in matches compared with 4.7 per 1000 h in training. However, to date no netball study has described the full profile of injuries by incidence, type, severity, impact, and characteristics across match and training contexts. At the elite level, there is acknowledgement that injuries occur more frequently in matches than training, but the quantitative evidence is limited (Janse van Rensburg et al., 2021; Toohey et al., 2022).

Beyond differences by exposure, injury risk also varies across competition level and age. Despite methodological variation across studies, comparisons consistently suggest that incidence and severity increase with competitive level: recreational and sub-elite cohorts generally report lower rates, whereas elite surveillance identifies higher incidence and more severe injuries, particularly at the knee (Downs et al., 2021; Janse van Rensburg et al., 2021; Langeveld et al., 2012; Toohey et al., 2022). Age-related patterns have also been observed, with younger players (<16 years) more likely to sustain upper-limb injuries, including arm, wrist, and hand fractures, while adults more commonly sustain lower-limb pathologies such as ankle and knee sprains and strains (Downs et al., 2021; Ellapen et al., 2015; McKay et al., 1996). Together, these findings highlight that contextual factors shape the risk and type of injury in netball, reinforcing the importance of accounting for these differences when interpreting epidemiological data and considering prevention strategies.

There is some evidence that injury incidence varies across the season, with community-level studies reporting elevated risk earlier in competition phases (McManus et al., 2006; Stevenson et al., 2000;). At higher levels, similar patterns have been suggested, with injuries clustering in the first half of the season (Toohey et al., 2022), although robust longitudinal evidence remains sparse. The distribution of injuries within matches is less consistent. Early studies suggested a peak in the opening quarter, particularly during the first 10 minutes of play (Hopper, 1986; Hopper et al., 1995a), whereas more recent data have indicated higher frequencies during the middle stages of competition, with a particular rise in quarter three (Janse van Rensburg et al., 2021; Langeveld et al., 2012). This shift may reflect differences in study design, match formats, or competitive demands across cohorts.

Despite the varied physical demands of playing positions, earlier studies generally found no clear differences between role and injury incidence (Hopper, 1986; Hopper et al., 1995a; Langeveld et al., 2012). However, more recent surveillance has identified potential positional trends. Sub-elite competition data highlight the centre position as carrying the greatest injury burden, followed by other mid-court roles (Sinclair et al., 2020). Similarly, at the 2019 Netball World Cup, the centre was the most frequently injured position (Janse van Rensburg et al., 2021), while Suncorp Super Netball data reported injuries distributed across all positions but with higher frequencies in centres and goal defences (Toohey et al., 2022). Collectively, these findings suggest that the centre position, given its extensive court coverage and involvement in both attack and defence, may be particularly susceptible to injury, though further work is required to establish the robustness of these positional differences.

Collectively, the evidence thus far indicates that injury occurrence in netball is shaped by contextual factors, but clear patterns remain difficult to establish due to methodological variation across studies. Addressing these gaps through systematic, standardised surveillance is essential to clarify the circumstances in which injuries arise and to guide more effective prevention strategies. The following section reviews the evidence to date on injury onset descriptors and injury-inciting events in netball, highlighting current understanding as well as areas where further sport-specific research is needed.

2.2.3 Injury Onset Descriptors and Injury Inciting Events in Netball

The assessment of how injuries occur in netball has involved multiple levels, ranging from broad descriptive classifications to more detailed analyses of the specific circumstances and actions leading to injury. This section is therefore structured in two parts. First, injury onset descriptors are reviewed, focusing on commonly reported distinctions such as contact versus non-contact, and the broad movement categories at injury onset (e.g., landing, cutting, collision) used in epidemiological studies. Second, research that has sought to analyse injury-inciting events in greater depth is examined, including video- and biomechanical-based approaches that capture situational factors, player behaviours, and joint or tissue loading. Finally, the implications of these findings are synthesised, highlighting the limitations of current evidence and the need for more robust and context-specific approaches to support injury prevention in elite netball.

2.2.3.1 Injury Onset Descriptors in Epidemiological Studies. As well as identifying injury frequencies and characteristics, some descriptive epidemiology has also documented the basic circumstances of injury onset. These studies have typically reported injury onset descriptors in broad terms such as contact versus non-contact, and by the activity being performed at the time of injury (e.g., landing from a jump, slipping, sudden stopping, or colliding with another player) (Hopper, 1986; Hume & Marshall, 1994; Joseph et al., 2019; Langeveld et al., 2012; McKay et al., 1996; Singh et al., 2013; Smartt & Chalmers, 2009). As outlined in Section 2.2.2.3, netball injuries include both acute and overuse pathologies, but descriptive reporting of injury onset has focused almost exclusively on acute events, leaving overuse mechanisms comparatively underexplored (Singh et al., 2013; Bissell & Lorentzos, 2018).

Within the current literature, landing from a jump is consistently reported as the most common cause for lower-limb injuries, particularly those affecting the ankle and knee (Ellapen et al., 2015; Hopper & Elliott, 1993; Hume & Marshall, 1994; Joseph et al., 2019; McKay et al., 1996; Pillay & Frantz, 2012; Saunders & Otago, 2009). Other frequently cited activity descriptors include slips, trips, and falls, as well as collisions with another player, which may result in both lower- and upper-limb injuries (Hides, 2018; Hopper et al., 1995a; Hume, 1993; Langeveld et al., 2012; Smartt & Chalmers, 2009). Some studies have attempted to place injuries within a broader tactical or positional context: Hopper and Elliott (1993) found that 54% of injuries occurred during attacking phases of play, whereas Hopper et al. (1995a) reported a higher proportion during defensive strategies (59%), most often in the defensive goal circle when contesting a pass. Broader analyses of ligament injury have also indicated that the majority of anterior cruciate ligament (ACL) ruptures in netball result from non-contact situations, highlighting the importance of intrinsic player movement patterns rather than direct collisions (Giannotti et al., 2009). While these classifications provide a useful overview of the activities most often associated with injury, they remain at a broad descriptive level. Variation in the terminology and categories used across studies has also been noted (Downs et al., 2021), which makes comparison across cohorts and synthesis of findings more challenging. More detailed analyses are required to capture the situational and biomechanical factors underpinning these events, which will be explored in the following section.

2.2.3.2 Analysis of Injury Inciting Events. While descriptive studies provide a useful overview of the activities most often associated with injury, they do not capture the situational detail or biomechanical processes through which these injuries occur. To move beyond broad categories such as “landing” or “collision,” researchers have increasingly sought to analyse the inciting event of injury, as defined earlier in Section 2.1.4.1 following the framework of Bahr and Krosshaug (2005). This approach emphasises not only what the athlete was doing, but also how and why the injury occurred, by considering contextual information such as opponent behaviour, playing situation, and whole-body and joint biomechanics.

Currently, the approaches used to assess the netball injury-inciting event in more detail have included laboratory-based biomechanical assessment, structured survey reporting, and, more recently, video-based analysis. Early work focused on laboratory-based biomechanical studies of fundamental movements, particularly landing, which demonstrated the high vertical (2.4–5.7 body weights) and horizontal (2.0–4.6 body weights) ground reaction forces generated during abrupt decelerations unique to netball, and recommended technique adaptations to minimise impact (Otago, 2004; Steele, 1990). Later, Stuelcken et al. (2013) identified that single-leg landings, typical in match play, produced substantial internal knee valgus forces, suggesting a potential biomechanical mechanism for knee injury. While these studies provided valuable insights, their laboratory design meant that they did not fully replicate the complex, dynamic conditions of match play, highlighting the need for more contextualised approaches to analysing injury-inciting events (Bahr & Krosshaug, 2005; Krosshaug et al., 2005). More recent research has applied structured observational methods to better capture the situational context of injury in netball. Mullally et al. (2023) used a structured survey approach to capture player-reported descriptions of injury events among recreational netball players. Their analysis highlighted landing, change of direction, and contact with another player as the most frequently reported inciting events, consistent with findings from earlier descriptive epidemiology. While this approach provided a more systematic account of perceived injury situations, it was limited by reliance on retrospective self-report and a non-elite cohort and therefore cannot fully replicate the objectivity or contextual detail achievable with observational or video-based methods.

Building on these studies, three investigations have now employed video-based methods to provide a more detailed and objective assessment of the inciting event in netball. These analyses captured the playing situation, player movement patterns and behaviours, and associated biomechanical mechanisms, allowing common scenarios to be identified for specific injuries. Two of these focused specifically on ACL injuries. Stuelcken et al. (2016) analysed 16 ACL ruptures in elite Australian players and identified two common scenarios: indirect aerial contact leading to unbalanced landings, and non-contact landings with altered trunk alignment and knee valgus collapse. Belcher et al. (2022) extended this work, confirming that most ACL injuries in netball occurred during single-leg, non-contact landings under defensive pressure, and emphasised the role of trunk control and lower-limb alignment. Combined, they highlight the predominance of non-contact landings in netball ACL injuries and the influence of situational and biomechanical factors. A third video-based study by Stuelcken et al. (2024) examined ankle injuries, demonstrating that most occurred during contested one-legged landings where the foot was forced into inversion, often in the presence of defensive contact. This work provided new detail on the typical loading conditions associated with lateral ankle sprains in elite netball, complementing the earlier ACL-focused analyses.

These studies demonstrate the value of systematic video methods for identifying common injury scenarios in netball. However, their scope has been limited to specific injuries, and despite recent progress toward sport-specific consensus on video descriptors (Mackay et al., 2023), there remains no validated framework for the consistent analysis of all injury-inciting events in the sport. While situational and behavioural descriptors and biomechanical factors are often considered together under the broader concept of the injury-inciting event, this thesis distinguishes between them to allow for more rigorous methodological development. Specifically, the situational and behavioural components are addressed through the development and validation of a comprehensive classification framework, while the biomechanical elements are explored in a pilot study to inform future consensus work.

2.2.4 Gaps and Limitations in the Current Netball Injury Literature

Although a relatively large body of netball injury research exits, the current evidence base contains important gaps and methodological limitations (Downs et al., 2021; Whitehead et al., 2021). These constrain understanding of the true extent and causes of injuries in the sport and restrict the ability to develop robust prevention strategies. The majority of existing studies (87%) have been conducted in a small number of Southern Hemisphere countries, particularly Australia, New Zealand and South Africa, with very limited research from the United Kingdom (Downs et al., 2021). While some research has examined elite players in Australia, South Africa and at international tournaments (e.g., Janse van Rensburg et al., 2021; Langeveld et al., 2012; Toohey et al., 2022), there has been little investigation of injuries in elite UK netball. Consequently, the extent to which findings from Australian, New Zealand, South African and international cohorts are transferable to UK netball, and specifically to the VNSL, remains unclear, particularly as elite netball environments differ across competitions in ways that may influence both athlete exposure and injury risk. These differences include competition structure and scheduling, the degree of professionalisation and athlete support provision, the training and match demands imposed across a season, and potentially tactical or playing-style demands (Whitehead et al., 2021; Brooks et al., 2020b). In addition, the VNSL has historically operated within a semi-professional structure, in contrast to more fully professional competitions such as Australia's Suncorp Super Netball (SSN), which may further influence athlete preparation, training exposure, recovery opportunities and access to medical and sports science support. Despite the Netball Superleague being established since 2005, no published systematic epidemiological studies have been conducted in this competition, highlighting the need for UK-specific research to establish whether injury patterns reported in other elite netball settings are representative of the VNSL and to inform prevention strategies relevant to the UK context. In addition to the lack of research conducted in elite UK netball, several other important gaps are evident. Most research has focused exclusively on match injuries, with little assessment of training-related injury patterns. Subsequent injuries are inconsistently reported and remain poorly understood in netball (Downs et al., 2021). Overuse injuries are also underrepresented, particularly in elite cohorts, despite emerging evidence suggesting they may account for a substantial proportion of cases (Bissell & Lorentzos, 2018; Sinclair et al., 2020). Evidence regarding positional differences in injury patterns are inconsistent, hindering a clear understanding of how injury risk may vary across playing positions in netball. Much of the available literature also predates the increasing professionalisation of elite competitions, and therefore may not accurately reflect the increased speed, intensity, and physical demands of the modern game (Whitehead et al., 2021). Only a small number of studies have used video-based methods to provide a more comprehensive assessment of injury-inciting events, including playing situation, player and opponent behaviours, and biomechanical characteristics. This research to date has also focused narrowly on ACL and ankle injuries, leaving little insight into other common or emerging injury types.

Beyond these knowledge gaps, the methodological quality of existing studies is highly variable. Many investigations have relied on retrospective hospital or insurance data, or short tournament-based surveillance, rather than prospective season-long designs, raising concerns regarding accuracy and representativeness. With the exception of recent work in the Suncorp Super Netball competition (Toohey et al., 2022), few systematic, ongoing surveillance systems have been reported in the published netball literature, resulting in a fragmented evidence base from which it is difficult to capture temporal trends. Considerable heterogeneity exists in injury definitions, severity classifications, and exposure reporting, which hampers valid comparisons across studies and cohorts (Downs et al., 2021). In addition, injury severity in the netball literature has largely been quantified using time-loss measures, with limited consideration of injuries that require medical attention and/or modified training or competition participation without resulting in complete absence from sport. This may underestimate the impact of overuse and other non-time-loss conditions in elite netball, where athletes may continue to train or compete while receiving treatment or participating with restrictions. Furthermore, few studies have reported measures of injury burden (incidence x severity), despite its value in identifying high-priority targets for prevention (Bahr et al., 2020).

To date, relatively little netball research has investigated the inciting event of an injury beyond a basic description in surveillance studies provided by the athlete and/or physiotherapist. Although recent research has applied more advanced video-based methods to analyse inciting events, these remain restricted to specific injuries and lack a standardised, validated framework for consistent and ongoing assessment of injury causes. Accordingly, there is a need for a dual approach: first, a validated framework capable of systematically capturing situational and behavioural factors across a broad range of injury types, and second, exploratory work to establish how biomechanical mechanisms can be incorporated in a consistent and practical manner. While the recent reviews by Downs et al.

(2021) and Whitehead et al. (2021) have highlighted some of these limitations, there remains a need for a more detailed and systematic appraisal of methodologies used in netball injury research. In particular, in the absence of a netball-specific consensus statement, future work must establish appropriate guidelines to support standardised surveillance and provide a validated framework for assessing injury-inciting events. Addressing these issues is essential to generate accurate, contemporary data and inform effective prevention strategies in elite netball.

2.3 Summary and Rationale for the Thesis

The prevention of sports injury is reliant on the use of sound methodologies to accurately address the first two stages of the sequence of prevention: (1) establishing the extent of the injury problem and (2) understanding injury aetiology and causation through examination of risk factors and the injury-inciting event, including associated biomechanical mechanisms (Bahr & Krosshaug, 2005; Finch, 2006; O'Brien et al., 2019; van Mechelen et al., 1992). The limited success of many prevention strategies may be attributed, at least in part, to an insufficient evidence base arising from non-standardised surveillance methods, and incomplete assessment of injury causes (Meeuwisse & Love, 1997; Finch, 2001; Bahr & Holm, 2003; Brooks & Fuller, 2006; Nielsen et al., 2016). Consequently, sustained efforts in sports injury research have aimed to strengthen methodological approaches, including the development of consensus definitions, enhanced surveillance frameworks, and more systematic analyses of injury causation (Bahr et al., 2020). While the preceding literature review has provided the broader theoretical and contextual foundation for this thesis by synthesising current knowledge on sports injury epidemiology, injury surveillance, injury causation and the netball injury problem, it has not systematically evaluated the methodological characteristics of the netball injury evidence base itself. At the time of this research, no netball-specific consensus statement or comprehensive methodological review was available to guide injury surveillance or injury-inciting event research. Accordingly, the scoping review was undertaken as a standalone study because its purpose extended beyond providing background context; it systematically evaluated the methodological quality and consistency of the netball injury evidence base in order to generate recommendations that directly informed the design of the empirical studies in this thesis and future netball injury research. This was essential to establish a stronger methodological foundation for the empirical work that followed and to support more rigorous investigation of the first two stages of the prevention model in elite netball research more broadly. In addition to the need for a systematic evaluation of existing methodological practices, there is a clear need to implement robust, prospective surveillance in elite netball, particularly in the UK. While recent studies in Australia, as well as international tournament surveillance, have provided valuable insight into elite cohorts (Janse van Rensburg et al., 2021; Toohey et al., 2022), no systematic surveillance has yet been conducted in the Vitality Netball Superleague. This leaves a major gap in understanding the incidence, severity, burden, and nature of injuries in the UK's premier competition. Importantly, such work must capture training as well as match exposure and address underexplored areas such as overuse and recurrent injuries, to provide a comprehensive and contemporary profile of the injury problem.

There is also a need to establish a standardised framework for analysing injury-inciting events. Progress has been made through video-based analyses of ACL (Stuelcken et al., 2016; Belcher et al., 2022) and ankle injuries (Stuelcken et al., 2024), which have provided valuable insight into common injury scenarios. However, current evidence is restricted to these specific injuries and lacks a validated system capable of consistently describing situational and behavioural factors across the full range of injury types. Recognising the importance of biomechanics, exploratory work is also required to determine how movement-related mechanisms can be systematically incorporated into such frameworks. In this thesis, the development of a standardised classification system therefore focuses on situational and behavioural aspects of injury-inciting events, while a separate pilot study examines approaches to integrating biomechanical mechanisms. Collectively, this body of work advances knowledge by establishing a more accurate and methodologically robust evidence base for injury in elite UK netball, strengthening the foundations on which effective and targeted prevention strategies can be developed.

Chapter 3: The Netball Injury Evidence Base: A Scoping Review of Methodologies and Recommendations for Future Approaches

This chapter presents a scoping review examining the methodological approaches used in netball injury research, originally published in *Systematic Reviews* (Horne et al., 2024; see also p. v for publication details). Building on the rationale outlined in Chapter 2, the review systematically evaluates how injury incidence, severity, burden, injury aetiology and injury causation have been investigated across the netball literature. By mapping study designs, data sources, definitions, and analytical approaches across the netball literature, this review identifies key strengths, limitations, and gaps in current practice. The findings provide an important methodological foundation for the subsequent empirical studies in this thesis, informing the design of the prospective injury surveillance study presented in Chapter 4 and the development of a structured injury-inciting event classification framework in Chapters 5 and 6.

3.1 Introduction

Netball is a popular court-based team sport, played predominantly by females. The international governing body reports over 20 million participants across 117 nations spanning Africa, Americas, Asia, Europe and Oceania, with ongoing global growth (World Netball, 2024). However, netball's intermittent, dynamic nature, involving repeated high-intensity sprints, jumps, landings, cuts and changes of direction (Davidson & Trewartha, 2008; Fox et al., 2013, 2014; Thomas et al., 2017), imposes considerable physical demands on players. These actions, combined with netball's unique footwork rule, generate substantial forces (Otago, 2004; Steele, 1990; Stuelcken et al., 2013) and player workloads (Bailey et al., 2017; Brooks et al., 2020; Cormack et al., 2014; Simpson et al., 2022; Young et al., 2016). Consequently, injury rates are high, ranging from 11.3–14 injuries/1000 player hour at the community level (Finch et al., 2002; Franettovich Smith et al., 2020; McManus et al., 2006; Stevenson et al., 2000), to elite rates from 54.8/1000 hour at the 2019 Netball World Cup (Janse van Rensburg et al., 2021) up to 500.7/1000 hour in South African players (Langeveld et al., 2012). Hence, effective prevention strategies are crucial to support growing participation and minimise the negative impact of injuries at all levels.

Sports injury research is commonly guided by van Mechelen et al.'s 'sequence of prevention' (van Mechelen et al., 1992) and the Translating Research into Injury Prevention Practice (TRIPP) (Finch, 2006) models, which emphasise the importance of identifying the injury evidence base to inform prevention strategies. Hence, the initial crucial steps involve understanding the sport's injury problem through injury surveillance and identifying the risk factors and injury-inciting events through which injuries occur. To ensure prevention strategies are effective, it is essential to collect accurate evidence using robust data collection methods. This requires the continual, systematic collection of high-quality data from injury surveillance systems across various settings (Ekergen et al, 2016), and a multifactorial approach to understand the complex interactions between multiple risk factors and injury-inciting events (Bahr & Krosshaug, 2005; Bahr & Holme, 2003).

Currently, there is limited review evidence describing the characteristics of methodologies used in netball injury research. Two recent netball reviews provide valuable synthesis of injury types, characteristics and risk factors, but only briefly address methodological considerations (Downs et al., 2021; Whitehead et al., 2021). Therefore, there is an urgent need for a comprehensive review of the methodologies used in netball injury research to establish the injury evidence base. Furthermore, while the recent consensus on netball video analysis framework (Mackay et al., 2023) provides guidance for the assessment of injury-inciting events from match video, there is currently no consensus statement to inform injury surveillance methods in netball. Consequently, a scoping review of this area was considered appropriate to provide a systematic overview of existing netball injury methodologies, identify areas of methodological inconsistency, and inform both future netball injury research and the empirical studies undertaken within this thesis. Therefore, the purpose of this scoping review is to evaluate the range and characteristics of methodologies used to describe 1) the incidence, severity and burden of injuries 2) the aetiology and causation of injuries in netball. This information will be used to provide recommendations for future research to ensure the accuracy of the evidence base for targeted netball injury prevention.

3.2 Methods

3.2.1 Protocol

This scoping review was conducted in accordance with the Preferred Reporting Items for Systematic reviews and Meta-analyses extension for Scoping Reviews (PRISMA-ScR) and PRISMA 2020 updated statement (Tricco et al., 2018; Page et al., 2021). The PRISMA-ScR checklist for this study is presented in Table A1, Appendix A.

3.2.2 Data sources and search strategy

A systematic and structured search strategy was developed with the assistance of a subject-specialist librarian. The electronic databases searched were SPORTDiscus, MEDLINE, CINAHL and Academic Search Complete (EBSCOhost), PubMed, Scopus, and Web of Science, covering the period from 1985 to 24 May 2024. The start date of 1985 was selected as Hopper (1986) is recognised as the first peer-reviewed study reporting netball injuries (Downs et al., 2021). The search terms applied across all databases were: “Netball*”

AND “Injur*” AND (“incidence” OR “prevalence” OR “epidemiolog*” OR “risk*” OR “mechanism*” OR “cause*”). A secondary search of the reference lists of included studies and Google Scholar was conducted to identify any additional eligible publications.

3.2.3 Study selection

Following the removal of duplicates, titles and abstracts were independently screened by the author and a second researcher using the predefined eligibility criteria. All articles that could not be excluded at this stage were retrieved for full-text screening. Where disagreements occurred, both researchers discussed the study until consensus was reached. Therefore, adjudication by a third researcher was not required.

3.2.4 Eligibility Criteria

Eligible studies included those reporting data on netball injuries across all ages and levels of competition. These studies investigated the incidence, severity and burden, and/or the aetiology (risk factors) and injury causation, including descriptions of the mechanism of onset or injury-inciting events. Only English-language, peer-reviewed journal articles were included. Studies were excluded if they did not investigate netball injuries, or they assessed the efficacy of prevention strategies, biomechanical factors in netball players unrelated to injuries, or the physiological/movement demands of the game. Analytical studies that included netball athletes as part of a broader sports cohort but generalised findings across sports were also excluded (e.g., Rigg et al., 2023 and Almousa et al., 2024). Additionally, review articles, consensus statements, abstracts, and reports were excluded. All definitions of netball injuries were accepted. Terminology relating to aetiology (risk factors) and injury causation (mechanisms of onset and injury-inciting events) varied across included studies and was therefore interpreted in accordance with the definitions outlined in Chapter 2.

3.2.5 Data extraction and analysis

The author and a second researcher reviewed the included studies and agreed classifications through discussion. Studies were classified as descriptive epidemiological (describing the incidence and nature of netball injuries) or analytic epidemiological studies (identifying the association between specific risk factors and netball injuries or injury causation descriptors), using an approach consistent with Pluim et al. (2006). The descriptive epidemiological studies were further classified according to data source as studies using hospital/clinic records and insurance claim databases (hospital/clinic and insurance studies), or studies using injury data from netball competitions and/or historical injury data of match-play (netball competition studies). All studies were also classified by study design as prospective cohort, retrospective cohort or cross-sectional studies.

Data extraction from the included studies was conducted by the author. Extracted data from 14 studies (22%; descriptive epidemiology n = 10 [23%]; analytic epidemiology n = 4 [19%]) were independently verified by a second researcher to support methodological rigour and data accuracy. Extracted variables included study details (authors and year of publication), study design and data collection methods, data collection period, country of origin, population characteristics (including level, age and sample size), injury definitions and classification methods, injury incidence and exposure reporting, injured body regions, risk factors assessed, and data analysis methods. Only risk factors specifically related to netball injury outcomes were extracted. Findings are summarised quantitatively using frequencies and percentages to map the extent, nature, geographical distribution and range of methodologies in the included studies.

3.3 Results

3.3.1 Study Selection

The database search yielded 655 studies, reduced to 199 following the removal of duplicates. After screening the titles and abstracts, 70 studies were identified for full-text screening. A further seven studies were identified through a secondary search of reference lists and 25 from Google Scholar, with 11 selected for full-text screening. Thus, a total of 81 studies received full-text screening. Subsequently, 65 studies were identified for inclusion in the review. A flowchart of the study selection process is shown in Figure 3.1.

3.3.2 Review Findings

Tables 3.1–3.3 provide a summary of the findings based on the study categories. Each table describes the study design and data collection methods, data collection period, country of origin, population, injury definitions, injury incidence and exposure methods, and body region. The findings are also presented in graphical and tabular formats in Appendix A. In the published journal version of this scoping review, extensive numeric citations were included to support individual Results statements. However, in this thesis, to maintain readability in author–date format, summary findings are primarily supported by the extraction tables (Tables 3.1–3.3), with individual studies cited selectively where key exemplars or exceptions are highlighted.

3.3.2.1 Study Design. Of the 65 studies included in the review, 44 (68%) were descriptive epidemiological studies, while 21 (32%) were analytic epidemiological studies. The descriptive studies utilised injury data from hospital/clinic records and insurance databases in 25 studies (57%) (Table 3.1), while 19 studies (43%) collected data from netball competitions (Table 3.2). Most descriptive studies assessing hospital/clinic records and insurance data were retrospective in design (n = 20, 80%), while the netball competition

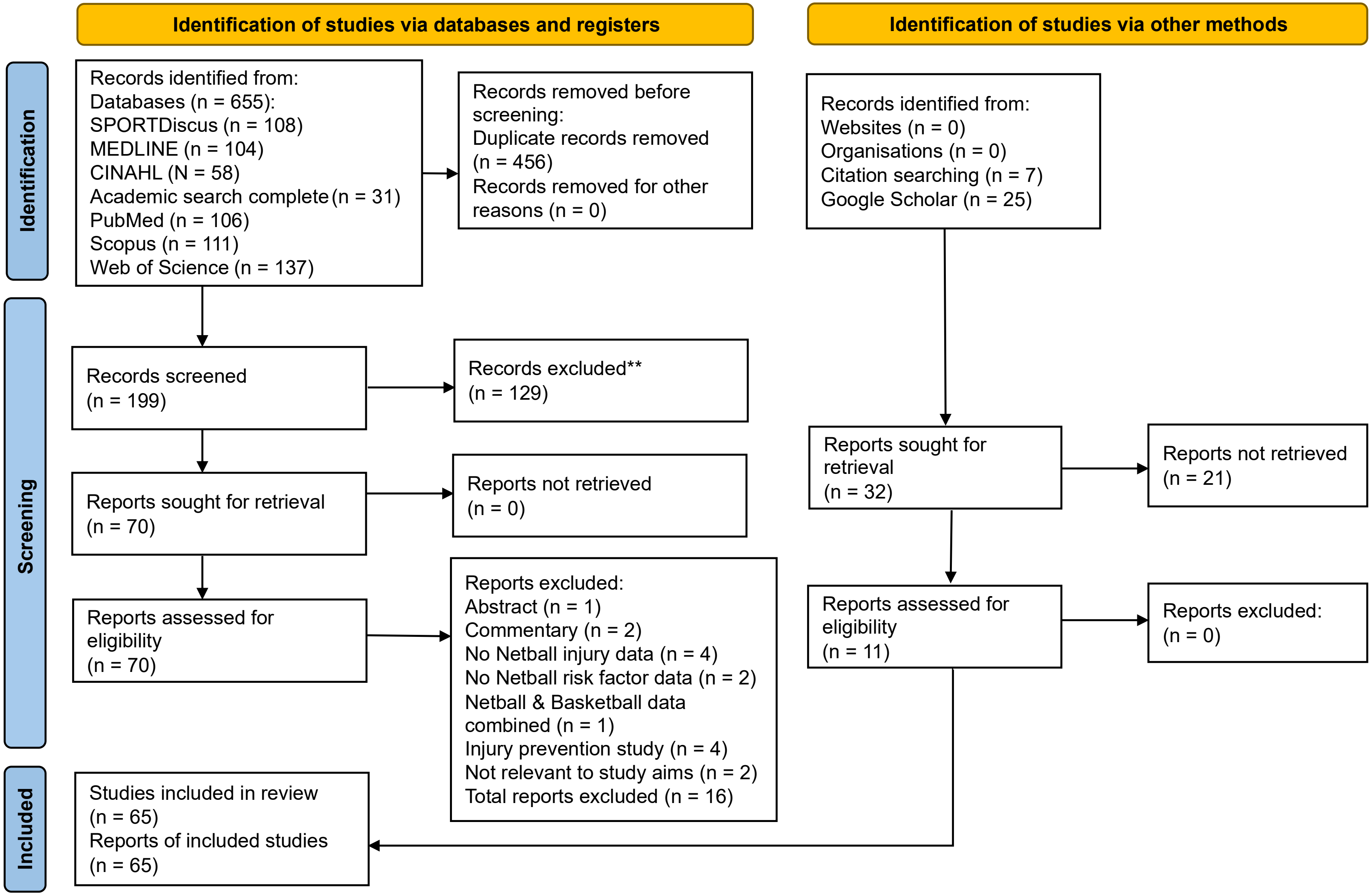

Figure 3.1 *Flowchart of scoping review selection process*

Table 3.1 *Methodological details and injury incidence of descriptive epidemiological netball studies using hospital records, clinic records and insurance claim databases*

Study	Country	Study design & data collection methods	Data collection period	Population	Injury definitions	Injury proportion or rate	Body region
Purdam (1987)	AUS	Prospective study: Data from physiotherapy dept at AIS	1986 10 m	Elite Netball and Basketball players at AIS. 20 Netball players, 105 inj.	All injuries presented to physiotherapy dept for treatment. Severity: based on no. treatments. Recurrent inj: inj > 1 m from discharge	Rate: 5.25 inj/player/y	All
Hume (1993)	NZ	Retrospective study: Data from HSS hosp morbidity data, Dunedin hospital A&E, ACC claims & Dunedin Sports injury clinic	1988–1992 1 y Clinic 1.7 y	Total population of Netball players in New Zealand, estimated to be 98, 680 in 1989–1990 age: 15+ y and children 5–15 y, 143 netball hospitalisations, age 5+ y	Any inj reported to hospital ED, ACC, sports injury clinic or recorded in health statistics. Severity: Abbreviated Injury Severity score, minor, moderate or severe	Netball hosp rate: 4.3/100,000 population/y 143/100,00 persons/y	All
Hume & Marshall (1994)	NZ	Retrospective study: Data from HIS mortality data, Dunedin hospital A&E, ACC & Dunedin Sports injury clinic claims	1978–1990 1 y Mortality 10 y	Netball population: 155,592 netball participants, 139 hospitalisations, age 15 y +	All injuries occurring in a place of recreation & sport, involving organised sporting activity or training for such presenting to hospital ED, ACC, sports injury clinic' Severity: Abbreviated Injury Severity score, minor, moderate or severe	Netball hosp rate: 89.34/ 100,000 population	All
Finch et al. (1998)	AUS	Retrospective study: Hospital ED data collated by NISU. Standardised form self-	1989–1993 5 y	General population: 98,040 sports and active recreation participants	All injuries presented to hospital ED. Severity: proxy measure,	Proportion: Child netball inj 3.7%; adult netball inj 6.6% of all sport inj presentations	All

		report, inj diagnosis and treatment completed by doctor		presenting to ED's. 2165 child (<15 y), 3098 adults (≥15 y) netball presentations	hosp admission after ED attendance.		
Love et al. (1998)	NZ	Retrospective study: Data obtained from NZ ACC database of sport injury dental claims	1993–1996 4 y	General population: 260 netball claims. Age 0–75+	Any new and minor dental claims made during each year. New claims are those that paid the claimant. Minor claims paid the health professional but not the claimant	Rate: 260 netball dental claims/y	Dental
Hassan & Dorani (2001)	UK	Prospective study: All sports-related fractures reported to A&E Dept in a district hosp in NE, ENG	1997–1998 1 y	General population: 1255 children with sport inj, 54 netball presentations Age 5–15 y	Any fracture while participating in sport that led to presentation at A&E. Severity: Injury Severity Score (ISS)	Proportion: 24% of A&E netball inj were fractures	All
Hon & Kock (2001)	MAL	Prospective study: All sports-related fractures presenting at Dept of Orthopaedic & Traumatology in a state hosp in W, MAL	1998–1999 1 y	General population: 113 patients presenting with fractures, 3 netball players. Age 7–59 y	All fractures sustained during sports activity presenting to Dept of Orthopaedic & Traumatology	Proportion: 2.7% of fractures in netball players	All
Cassell et al. (2003)	AUS	Retrospective study: Data from hosp admissions (VAED dataset), hosp ED presentations (VISS) & GP presentations (ELVIS project) in area of a regional hosp in Victoria, AUS	1994–1995 1 y	General population: estimated 69,663 in study area. 2300 medically treated sports inj; netball 81ED, 67 GP Age 4+ y	All sporting injuries receiving medical treatment recorded by 3 injury surveillance systems. Severity: length of hosp stay Injury Classification: ICD	Proportion: ED 6.9%; GP 6.7% netball inj presentations	All
Chong & Tan	SNG	Retrospective study: Data from medical	1999–2002 4 y	General population: 259 patients with ACL	All female ACL injuries requiring reconstruction	Proportion: 31% ACL inj to netball players	Knee

(2004)		records & telephone interviews of all ACL reconstructions from Dept Orthopaedic Surgery in E, SING		ligament reconstruction: 13 female patients, 4 netball players (3 school, 1 club). Age 13–38 y			
Otago & Peake (2007)	AUS	Retrospective study: Accepted netball insurance claims in Victoria, AUS	1999 1 y	Total population of registered state netball players covered by insurance scheme: total 87,331. 829 insurance claims. Age 10 y+	All inj resulting in accepted insurance claims Severity: cost of injury	Rate: 9.49 inj/1000 netball players	All
Smartt & Chalmers (2009)	NZ	Retrospective study: Data from Netball inj hosp records, linked public hospital discharges, and ACC claim datasets	2000–2005 6 y	Estimated population of netball participants in New Zealand: 200,000 players, 1126 netball inj cases. Age 5 y +	All netball inj cases recorded in hospital discharge datasets. Severity: Injury Severity score (ICISS) Injury Classification: ICD	Rate: 5/100,000 netball participants	All
Flood & Harrison (2009)	AUS	Retrospective study: Netball and basketball inj resulting in hosp admission, data from National Hospital Morbidity Database	2000–2004 4 y	Netball and Basketball population estimates. 5090 basketball-related, 4596 netball-related hospital admission. Age 5–54, mean 26.3 ±10.9 y	All netball and basketball patients discharged from a private or public hospital Injury Classification: ICD	Av annual hosp rates: Netball 1.4/1000 participants	All
Gianotti et al. (2009)	NZ	Retrospective population-based study: Knee ligament inj data from ACC records	2000–2005 5 y	General population of New Zealand: approximately 4.1 million people. 3997 sport-related inj: 746 netball. Age 0–85 y+	Any personal knee ligament injury resulting in an ACC claim made at time of medical treatment	Proportion: 18.7% of all sport-related ACLS inj	Knee
Welch et al. (2010)	NZ	Retrospective case series: Data on sports-related dental injuries	1999–2008 10 y	General population of New Zealand: Active adults 2.7 million,	All new oralfacial ACC claims received in financial years 1999 to 2008.	Proportion: netball 3.9% of all sport-related claims	Dental

		from ACC records		700,000 young people. 275,130 new claims. Age range 0 – 61 y+			
Gwynne-Jones et al. (2011)	NZ	Retrospective study: Data from ED, in-patient, surgical audit and physiotherapy dept records	1999–2008 8.5 y	General population: 363 patients. 285 sport-related inj, 88 netball players. Age 15–60 y	A complete, traumatic closed rupture of the Achilles tendon in hospital patients. Recurrent inj: re-ruptures	Proportion: netball 24% of inj	Achilles Tendon
Jansen et al. (2011)	AUS	Retrospective study: ACLR data from National Hospital Morbidity Database	2003–2008 5 y	General population: 50,187 patients with ACLR. Annual netball ACLR 1085. Age 5–75 y +	All ACLR in study period concerning the population Injury Classification: ICD	Annual ACL reconstruction rate: 188/100,000 participants	Knee
Fernando et al. (2018)	AUS	Retrospective case series: Sport & recreation injuries presented to ED's across 38 hosp in Victoria, AUS, data recorded in Victorian Emergency Minimum Dataset	2012–2015 3 y	General population: 171,541 ED presentations, 5438 Netball. Age 5 y +	All sports & recreation injuries reported to ED's	Annual inj rate: 38.7/100,000 participants	All
Joseph et al. (2019)	AUS	Retrospective study: Netball specific inj recorded in national insurance claim database over 1 season	2016 1 y	All players registered to play in Netball Australia organised competition receiving insurance cover. Total participants 413,800 players. 1215 netball inj claims. Mean age 34 ± 17 y	Any netball injury resulting from an accident during matches or training for an organised Netball Australia competition Injury Classification: OSIICS	Annual inj rate: 2.9 claims per 1000 participants	All
King et al. (2019c)	NZ	Retrospective study: Sport-related inj data	2012–2016 5 y	General population: 853,824 total claims.	Any injury assessed by a registered health practitioner	11,748 moderate-to-serious inj claims; 9	All

		from ACC. Inj claims from 5 sports, including netball		11,757 total netball claims.	as a result of sports participation. Severity: cost of injury	serious inj claims	
Kirkwood et al. (2019)	UK	Retrospective ecological study: Sports injury data from ED data & in-patient data from 2 hosp in Oxfordshire, ENG	2012–2014 2 y + 2 m	General population: Children and adolescents attending hosp; 11,676 sports inj ED attendances. Age 0–19 y	Any sports-related inj attendances at A&E depts. Injury Classification: ICD	157 netball injuries	All
Sutherland et al. (2019)	NZ	Cross-sectional study: Sports injury ACLR data from ACC	2009–2016 8 y	General population: 20,751 male and female ACLRs. Netball 3088 claims.	Any injuries involving claims made for primary ACLR	Proportion: netball 20% of sports-related ACLR claims	Knee
Belcher et al. (2020)	NZ	Retrospective study: Audit of netball injury ACC claims	2008–2017 10 y	Mean age 29 ± 11 y	New netball-related claims involving 4 treatments or more, or cost > $100NZD	Rate (10 y): Ankle 77.8/1000 players, Knee 71.6/1000 players.	Ankle & Knee
Chan et al. (2021)	SING	Retrospective study: ACLR data from electronic medical records & registry data of tertiary public hospital in SING	2013–2016 3 y + 6 m	Total population of Netball New Zealand affiliated members. Age 10–24 y	All ACL injuries involving primary ACLR, on ACLR registry.	Proportion: netball injuries 4.3% of all ACLR patients	Knee
Mitchell et al. (2021)	UK	Cross-sectional study: Acute sports-related inj presented to fracture clinic at Peterborough city hospital, ENG	2018–2019 1 y	General Asian population: 696 male and female patients, 21 netball inj Mean age 25.7 ± 7.2 y	All sports-related inj in school age children, reporting to fracture clinic. Severity: surgical treatment equals severe injury	Proportion: 2% required surgery, 11% required physiotherapy.	All
Brimm et al. (2023)	AUS	Retrospective study: Sports-related hosp in Queensland, AUS	2012 – 2016 5 y	General population of school age children, 54 netball inj. Age 6–18 y General population:	Any patients with sports & leisure-related inj admitted to public and private hospitals. Injury Classification: ICD	Rate: Total 4.9/100,000 Females: 8.8/100,000 Males: 111, 0.9/100,000	All

	76,982 hosp. Netball 1150 hosp. Age: children ≤14 y to older adults ≥65 y.	

Note. AUS = Australia; NZ = New Zealand; UK = United Kingdom; ENG = England; MAL = Malaysia; SING = Singapore; AIS = Australian Institute of Sport; Inj = injury/injuries; Hosp = Hospitalisation; y = years; m = month; SD = standard deviation; HSS = Health Statistical Services; ACC = Accident Compensation Corporation; A&E Dept = Accident and Emergency Department; HIS = Health Information Service; NISU = Australian National Injury Surveillance Unit; NE = North East, W = Western; VAED = Victorian Admitted Episodes Dataset; ED = Emergency Department; VISS = Victorian Injury Surveillance System; GP = General Practitioner; ELVIS = Extended Latrobe Valley Injury Surveillance; ICISS = International Classification of Injury Severity Score; ICD = International Classification of Diseases; OSIICS = Orchard Sports Injury and Illness Classification System; E = Eastern; ACL = Anterior Cruciate Ligament; ACLS = Anterior Cruciate Ligament surgeries; ACLR = Anterior Cruciate Ligament reconstruction, IRR = Incidence Rate Ratio’s; NZD = New Zealand Dollar

Table 3.2 *Methodological details and injury incidence of descriptive epidemiological netball studies of competitions*

Study	Country	Study design & data collection methods	Data collection period	Population	Injury definitions	Injury proportion or rate & athlete exposure	Body region
Hopper (1986)	AUS	Prospective cohort study: State competition: Junior 124, Senior 324 teams. Questionnaire: Self report + physio post treatment.	1983 1 x14 wk season	Recreational to competitive level. 3,108 netball players, 158 inj. Age Junior: 12–15 y; Senior 16 y +	Any injury presenting to First Aid room requiring immediate medical care or with some form of disability. Minor inj not included	Rate: 50.82/1000 players/match	All
Hopper et al. (1995a)	AUS	Prospective cohort study: State competition Questionnaire: Self report + physio post treatment.	1985–1989 5 x 14 wk seasons	Recreational to competitive level. 11,228 netball players, 608 inj. Age 14 y + mean 18.8 ± 5.6 y.	Any inj presenting to First Aid room requiring immediate medical care or presented with some form of disability. Minor inj not included. Severity identified by Physio, graded 1, 2 or 3 based on symptoms	Rate: 0.054/player/match	All
McKay et al. (1996)	AUS	Prospective cohort study: Netball and basketball State competitions. Trained observers recorded inj, players completed questionnaire & follow-up telephone interviews	1991–1992 2 x seasons	Elite & recreational level. 9,190 netball players, 159 inj. Mean age 27.2 ± 7.8 y	Bodily harm to player causing stoppage of play, substitution or obvious disability. Severity classified on time-loss and treatment graded trivial, minor, substantial, major, severe	Rate: 17.3 inj/1000 netball players.	All
Pringle et al. (1998)	NZ	Cross-sectional study: Trained observers recorded rugby union, rugby league & netball inj data. Standardised incident form, follow-up	Not known 4 wk period of 1 season	Junior recreational level. 1512 netball players, 15 inj Age 5–16 y	All inj that impaired a player's performance. Severity classified on time-lost as minor or moderate	Rate: 13inj/1000 player hrs. Exposure: Not clear	All

		telephone calls by Physio's monitored to recovery					
Hume & Steele (2000)	AUS	Prospective cohort study: State competition: 94 teams. Questionnaire completed by inj player reporting for medical treatment during	1995 3-day champs	Sub-elite level: U17, U19, U23 & Open (over 23y). 940 netball players, 131 inj. Mean age 14.4 ± 4.4 y	All players reporting for treatment of any inj incurred during the 3-day champs	Rate: 139.4 inj/1000 players; 23.8/1000 playing hrs Exposure: Estimated individual player match hrs	All
Stevenson et al. (2000)	AUS	Prospective cohort WASIS study: Baseline data and incidence of injury, self-report questionnaire with follow-up telephone interview once/m over season	1997 1 x 5m season	Community level. 258 netball players, 112 inj Age 9–56 y, mean 22 y	Council of Europe definition: any inj occurring during sports participation leads to: reduction in sports activity, need for advice/treatment and/or adverse economic or social effects. Severity based on level of treatment graded minor, moderate or severe	Rate: 12.1 inj/1000 hrs of participation Exposure: Mean individual combined match and training hrs	All
Finch et al. (2002)	AUS	Prospective cohort WASIS study: Baseline data and inj incidence; self-report questionnaire with follow-up telephone surveys once/m over season	1997– 1998 2 x 5 m seasons	Community level 247 netball players, 216 inj Mean age 22 ± 8 y	Council of Europe definition: see Stevenson et al. (2000) Severity based on level of treatment graded minor, moderate or severe	Rate: 11.3 inj/1000 hrs of participation Exposure: Mean individual combined match and training hrs	All
Finch & Cassell (2006)	AUS	Retrospective cohort study: Self-report household telephone survey of sports & active recreation inj	Not known Previous inj every 2 wk over 12 m	Community/ recreational level. Total 1084 participants; 648 across all sports, 34 net inj. Age 5 y+.	Any inj during sport or active recreation regardless of treatment or time loss. Significant injury: required treatment, interfered daily	Rate: 19 inj/10,000 population; 51/1000 participants	All

					activity &/or impacted subsequent activity		
Langeveld et al. (2012)	SA	Prospective cohort study: USSA & National champs. Questionnaire completed by team manager, coach or medical staff daily	2009 3 x champs 4-6 days	Elite/Sub-elite U19, U21 & Senior players. 1280 netball players, 205 inj Severity: No missed matches	Any physical complaint during a netball match or training requiring medical attention. Severity: no. missed matches. Recurrent inj: same type as index inj post recovery from index inj	Rate: 500.7 inj/1000 playing hrs. Exposure: Individual player match time (mins) before inj	All
Pillay & Frantz (2012)	SA	Cross-sectional study: Self-report questionnaire of player inj collected at a tournament	2010 1 x previous season	Elite/Sub-elite level. Total 254 players, 301 inj Age: 55 Club 24.1 ± 6.3 y; 147 Provincial 23.9 ± 5.1; 52 National 24.3 ± 4.3.	Any physical complaint during match or training irrespective of need for medical attention or time loss. Severity based on symptoms graded as mild, moderate, severe. Repeated inj: inj to same site	Rate: 1.9 inj/player/ season	All
Singh et al. (2013)	JAM	Retrospective cohort study: Self-report questionnaire of player inj & related inj factors	2003 –2007 Previous inj 5 y	Elite/Sub elite players: Senior (over 21 y), U21 & U16 age groups. Total of 59 players, 70 inj	Trauma to body resulting in the cessation of play. Severity: no definition used Grade I, II or II. Recurrent inj: repeated inj to same site	Proportion: 68% players inj	All
Ellapen et al. (2015)	SA	Retrospective cohort study: Province School League: 80 Schools. Self-report questionnaire of netball inj history & related inj factors	Not known Previous inj 12 m recall period	Junior (school) level. Total 413 players, 258 inj Age 13–17 y.	Distress or pain while playing netball preventing physical activity for > 1 day. Pain severity rating 1–5: no pain, mild, moderate, severe, worst pain	Proportion: 62% of players inj	All
Bissell &	AUS	Prospective cohort	Not known	Recreational/Club level	All players reporting overuse	Inj prevalence:	Overuse

Lorentzos (2018)		study: 1 club. Self-report questionnaire on overuse inj (Oslo Sports Trauma Center questionnaire). Recorded 1 x per wk.	1 x 12 wk season	players. Total 37 players, 152 overuse inj cases in 42 players. Age: adults < 45 y	inj during the 12 wk season. Severity score 0–25: based on time-loss and pain	77.7%. 25% significant overuse inj	inj of knee, ankle & shoulder
Smyth et al. (2020)	AUS	Prospective cohort study: ANNC competition: 16 teams. Medical attention & self-report inj data	2018 6-day champs	Sub-elite level netball players. Total 192 players; 96 U17, 96 U19. 103 inj	Concurrent IDCF: Any inj that required physio assessment irrespective of time-loss. Sports incapacity: inj resulted in any match time-loss or reduction in capacity based on HPQ Injury Classification: OSIICS	Rate: 89.4 inj/1000 player hrs. Sports incapacity: 19.1 inj/1000 player hrs. Exposure: Individual athlete & mean team match exposure (no. athletes x no. teams x matches x min/match)	All
Botha et al. (2020)	SA	Cross-sectional study: 2 junior tournaments. Standardised self-report questionnaire on inj & training modalities	2015 + 2017 Duration not stated	Junior (U15, U16) & Senior (U19) school level netball players. Total 560 players, 46 inj: 220 U15, 17 inj; 220 U16, 20 inj; 120 U19, 9 inj	Any physical complaint during netball match-play or training requiring medical attention	Rate: total 22.5 inj/1000 playing hrs. U15: 22.8; U16: 22.8; U19: 21.2. Exposure: Mean team match playing hrs (no. matches x game length x players)	All
Sinclair et al. (2020)	SA	Cross-sectional study: School & State leagues. Inj diagnosed by doctor. Inj questionnaire completed with support of research assistant weekly	2017–2018 2 x seasons	U18 secondary school, U19, U21 & Senior Free State netball players. Total 96 players, 48 inj	Any physical complaint during netball match-play or training requiring medical treatment, loss of time or performance restriction. Severity: based on time-loss categories slight, minor, moderate, major	Rate: 33.9 inj/1000 hrs of match play Exposure: Mean match hours (1 match = 14 playing hrs)	All
Janse van	SA	Prospective cohort	2019	Elite level players.	Any newly acquired inj &	Rate: 54.8/1000	All

Rensburg et al. (2021)		study: Netball World Cup 2019: 16 teams. Inj surveillance forms completed by team physician &/or venue doctors.	10-day champs	16 national teams. Total 192 players, 49 inj Mean age 26.6 y (95%CI: 25.9–27.3)	exacerbations requiring medical attention during the tournament. Severity: number days lost Recurrent inj: recovery from index injury and subsequent presentation of same inj	player hrs. Prevalence 20.3% Exposure: Mean individual match hrs (1 hr x 7 players = 7 match player hrs/team/match)	
Toohey et al. (2022)	AUS	Prospective cohort study: SSN competition: 8 teams. Inj data collected during pre-season, in-season & off-season. Data recorded by doctor or Physiotherapist using centralised database	2017 – 2019 3 x 17 wk seasons	Elite level players. 8 teams, total 119 players, 866 inj. Mean age 25.4 ± 4.2 y	All inj requiring medical attention and time-loss. Severity based on length of time-loss. Injury burden: mean severity x inj incidence Subsequent injury: any inj following initial inj in time period Injury Classification: OSIICS	Rate: 3.9 inj/365 player days. Exposure: Pre-season & in-season team hrs based on player contract days (no. contracted players x no. teams x no. surveillance days)	All
Kumari & Chaudhary (2023)	IND	Prospective cohort study: All India inter-university tournament. 52 teams Data recorded at the Central University of Haryana health centre.	Not known	University level players. Total 14 players injured. Age range 18–24 y	Inj involving foot pain, finger pain, finger cuts, leg pain, and ankle twist referred to University health centre	Not provided: 3 finger pain; 7 leg pain; 2 ankle twist; 1 finger cut; 1 foot pain.	Foot, finger, leg, ankle

Note. AUS = Australia; NZ = New Zealand; SA = South Africa; JAM = Jamaica; UK = United Kingdom; IND = India; Inj = injury/injuries; Physio = Physiotherapy/Physiotherapist; Champs = Championships; y = year; m = month; wk = week; hrs = hours; Av = Average; no. = number; mins = minutes; U = Under; SD = standard deviation; CI = confidence interval; AIS = Australian Institute of Sport; NISU = National Injury Surveillance Unit; WASIS = Western Australian Sports Injury Study; ANNC = Australian National Netball Championships; IDCF = Concurrent Injury Definitions Concept Framework; HPQ = Oslo Sports Trauma Research Centre Health Problems Questionnaire; SSN = Suncorp Super Netball League; OSIICS = Orchard Sports Injury and Illness Classification System

Table 3.3 *Methodological details and results of analytic epidemiological netball studies*

Study	Country	Study design & data collection methods	Data collection period	Population	Injury definitions	Injury proportion or injury rate & exposure	Body Region	Risk factors
Hopper & Elliott, (1993)	AUS	Retrospective & Prospective cohort study: National champs. Questionnaire of inj history & inj data recorded during champs. Risk factors measured at start of champs.	1988 Multi-day champs	Elite/Sub-elite level: U16, U21 & Open (over 21). Total 228 players, 52 inj. Mean age: U16: 14.8 y, U21: 19.2 y, U21 23.7 y	A lower limb or back disability that caused pain or some form of dysfunction. Severity based on deformation grades 1–3	Proportion: 23% sustained lower limb or back inj	Lower Limb & Back	Age, previous inj, inj side, weak joints, lower limb and back podiatric variables: foot types & hip extension & external rotation (back problems), level of comp, taping/bracing, quarter & time in quarter
Hopper et al. (1994)	AUS	Retrospective cohort study: National Champs Questionnaire of inj history prior to champs. Risk factors measured during champs	1988 Multi-day champs	Elite/Sub-elite level: U16 & U21. Total 204 players, 188 inj. Mean age U16: 14.8 U21: 19.1 y	All previous lower limb injuries	Proportion: 90% lower limb inj in career	Lower Limb	Previous inj, inj side, foot type
Hopper et al. (1995b)	AUS	Prospective cohort study: State competition: 8 states Questionnaire completed by players & physio post treatment during 14-wk State comp. Risk factors recorded pre-season	1989 1 x 14 wk season	Elite to recreational level. 72 Senior players, 22 inj Age 15–36, mean 20.6 ± 3.6.	Any inj presenting to first aid room requiring immediate medical care or resulting in some form of disability. No minor injuries. Severity based on deformation grades 1–3	Proportion: 30.6% players inj	All	Age, ht, mass, somatotype, hypermobility, static balance, muscular power, anaerobic fitness, level of comp, time-loss, treatment required, referral type

Hopper (1997)	AUS	Prospective cohort study: National champs Lower limb and back inj diagnosed, treated & recorded by physio during champs. Risk factors measured pre-season	1988 Multi-day champs	Elite/Sub-elite. Total 213 U16, U21 & Open players, 52 inj. Mean ages: U16 14.8 ± 0.4, U21 19.2 ± 2.2, Open 23.7 ± 3.6 y	A lower limb or back disability that caused pain or some form of dysfunction	Proportion: 24% sustained lower limb or back inj	Lower Limb & Back	Age, playing position, somatotype, level of comp,
Smith et al. (2005)	AUS	Cross sectional study: NSW Junior League Questionnaires of players self-reported inj. Risk factors measured during early season.	All previous inj	Junior level. Total 200 players from 13 clubs, 69 injuries. Age 6-16, mean 11 ± 2.5 y	Trauma to body part causing player to cease play & miss minimum 1 game	Proportion: 35% of players inj playing netball	All	Age, ethnicity, playing position, previous netball inj, other sport inj, playing experience (y), no. games/week, protective equipment, hypermobility (Beighton) score
McManus et al. (2006)	AUS	Prospective cohort WASIS study: Risk factors and injury incidence from 2 consecutive 5 m seasons, baseline questionnaire and monthly telephone interviews.	1997–1998 2 x seasons	Community level. Total 368 players, 272 inj. Age 66% 16–30 y.	Inj during sport causing reduction in activity, need for medical advice &/or adverse social or economic effects. Recurrent inj: repeated index inj post recovery	Rate: 14 inj/1000 player hrs Exposure: Individual combined match and training hrs	All	Previous inj history, playing experience (y), time in season, training in previous y, pre-season training, training/wk, warm-up/cool-down, open to new ideas
Ferreira & Spamer (2010)	SA	Prospective cohort study: Injuries recorded by physio at clinic. Risk factors recorded pre-& post season	2007 1 x season	Elite North-West University first team. Total 25 players, 46 inj. Age 18–23 y	All inj during match or training activities. Severity based on time-loss graded 1, 2 or 3	Rate: 1.84 inj/ player	All	Time in season, Anthropometrics: ht, mass, BMI, body fat %; Biomechanics: symmetry, dynamic mobility, local stability of limb-pelvic region, hip girdle, lower limb

								(knee and foot); Physical ability: agility, balance, explosive power
Maulder (2013)	NZ	Prospective cohort study: Inj self-reported every 2 weeks via email/phone. Risk factors recorded pre-season	Not Known 1 x 6 m season	Elite and Sub-elite level. Total of 24 players, 9 inj Age 18–25, mean 21.6 ± 3.2 y	All lower limb inj that affected performance & required medical treatment, causing missed training &/or game time.	Proportion: 37.5% of players inj	Lower Limb	Lower limb dominance & asymmetry, agility performance: unanticipated straight-run & 180° turn tasks
Coetzee et al. (2014)	SA	Prospective cohort study: USSA & National champs. Questionnaire of injuries & training history modality, completed by team manager, coach or medical staff daily during champs	2009 3 x champs 4-6 days	Elite level. U19, U21 & Senior. Total of 1280 participants, 205 inj.	Same as Langeveld et al. 2012	Rate: 500.7 inj/1000 playing hrs Exposure: Individual player match time (mins) before inj	All	Training volume, training type (core stability, neuromuscular, biomechanical & proprioceptive training), playing surface.
Attenborough et al. (2016)	AUS	Cross-sectional study: Recurrent ankle sprain history collected pre-season via self-report questionnaire. CAI measures: perceived & mechanical ankle instability.	2013–2014 1 x season	Elite/inter-district & club level. 42 Club, 54, Elite/inter-district: total 96 players, 69 inj. Mean age: 21.5 ± 6.3 y	CAI: recurrent ankle sprain &/or perceived ankle instability &/or mechanical ankle stability. Severity: CAIT-Y Score. Recurrent sprain: 2 or more sprains to same ankle	Proportion: 72% previous ankle sprain, 47% recurrent sprain	Ankle	Previous inj, static & dynamic balance (SEBT), age, ht, mass, level of competition,
Stuelcken et al. (2016)	AUS	Retrospective study: ANZ champs Medically diagnosed,	2009–2015 Televised	Elite level. Total of 16 players, 16 ACL	All televised ACL injuries during ANZ champs	Proportion: 63% left knee, 37% right knee	Knee	Game situation, movement patterns, player behaviour &

		televised ACL injuries. Inj mechanisms identified from video.	games 6 y 3m	inj. Age not reported				potential mechanism at time of injury, playing position, match quarter.
Attenborough et al. (2017)	AUS	Prospective cohort study: Ankle inj & exposure data collected by team physio or via self-report. Risk factor data collected pre-season	2013–2014 1 x season	Elite/inter-district & club level. Total 94 players, 11 inj. Mean age: 21.5 ± 6.3 y	All ankle injuries resulting in time loss ≥ one full match or training session Severity: CAIT-Y score	Rate: 1.74/1000 h; 6.75/1000 h match-play; 0.40/1000 h training Exposure: Individual player recorded match & training hrs	Ankle	Perceived ankle instability, ankle sprain history, joint laxity, muscular power, static & dynamic balance (SEBT), age, ht, mass, level of competition,
Pickering Rodriguez et al. (2017)	AUS	Prospective cohort study: National & State champs. Lower body overuse inj data reported by physio or self-report. Risk factor data collected pre-season &1 x/month across season	2013 1 x 14 wk season	Elite & sub-elite level. Total 29 players, 12 inj. Mean age 24.1 ± 3.2 y	Non-contact, match or training, soft tissue damage of lower limb resulting in time loss ≥ 1 game	Rate: 11.29/1000 h; Elite: 19.35/1000 h; Sub-elite:7.13/1000 h. Exposure: Team combined match & training hrs	Lower Limb	Lower body stiffness age, ht, mass, level of competition,
Whatman & Reid (2017)	NZ	Cross-sectional study: Self-report overuse knee & ankle inj history (Oslo Sports Trauma Center questionnaire). Risk factor data collected during tournament	Not Known Previous inj 12 m	Junior Secondary School level. Total 166 players, mean age 16 ± 1 y	All ankle & knee inj with no identifiable event responsible for onset. Substantial inj: moderate or severe reduction in or inability to compete in matches or training	Prevalence Knee: 31%, Substantial inj: 10%; Ankle: 51%, Substantial inj 24%	Ankle & Knee	Previous inj, level of play, movement competency: dorsiflexion ROM, frontal-plane knee angle + position during single-leg squat & drop jump, vertical jump ht & power
Horgan et al. (2021)	AUS	Retrospective cohort study: National	2015–2018	Elite & Pre-elite level. Total 536	Loss or abnormality of	Daily probability 0.98 ± 0.06%	All	Training preparedness (fatigue, mood,

		Secondary School tournament. Inj & risk factor data collected form self-report and medical diagnosis, recorded on AIS AMS	4 y	players, 1122 inj. Mean age 18.8 ± 4.6 y	bodily structure or functioning during training or competition diagnosed as a medically recognised inj			motivation, soreness, sleep duration & quality), training load, time following inj
Franettovich Smith et al. (2020)	AUS	Prospective cohort study: 1 club playing across 9 divisions. Inj recorded by player/coach. Follow-up telephone call from researcher. Risk factor data recorded pre-season via questionnaire.	2016 1 x season	Community/ recreational level. Total 269 players, 169 inj. Age 7–42 y	All lower limb bodily damage caused by competing or training for netball	Rate: 13.8/1000 h. Match: 32.3, Training 4.7/1000 h Exposure: individual player recorded match & training hrs	All	Age, ht, mass, BMI, previous inj, netball hrs/wk, other physical activity hrs/wk, use of warm-up & cool-down, taping or bracing, footwear, ankle dorsi-flexion ROM, level of comp, time in season, season game time, training time
Sinclair et al. (2021)	SA	Prospective cohort study: Self-administered inj report questionnaire, weekly follow-up. Risk factor data recorded pre-season	2017–2018 1 x season	U18 secondary school, U19, U21 & Senior Elite Free State level. Total 110 players, 48 inj	Same as Sinclair et al. 2020	Rate: 33.9 inj/1000 hrs of match play Exposure: Team mean match hours (1 match = 14 playing hrs)	All	Age, playing position, previous inj history, ht, wt, BMI, body fat, balance, flexibility, explosive power, upper & lower body strength, core strength, speed & agility
Belcher et al. (2022)	NZ	Cross-sectional study: ANZ or International comps. Systematic video analysis of medically diagnosed, televised ACL inj	2011–2019 8.5 y	Elite level. Total 21 players with ACL inj Age not reported	All televised ACL inj during match-play	Proportion: 57% left, 43% right knee.	Knee	Game situation, movement patterns, player behaviour, inj mechanism at time of injury, inj side, playing position, match quarter
Mullally et al.	UK	Cross-sectional study:	Not	Recreational	Any netball inj	Rate: Upper limb:	All	Injury situations,

(2023)		Online survey; self-report inj previous 12 m, and risk factors. Administered worldwide	Known Previous inj 12 m recall period	level. Total 193 players, 73 upper limb, 182 lower limb inj. Age >18 y, mean 33.7 ± 11.2 y	sustained in previous 12 m, & knee inj in previous 5 y, which prevented participation in ≥1 match or training session	37.8 inj/100 players/y Lower limb: 94.3 inj/100 players/y		previous inj, playing position, match or training inj, match quarter, time-loss, treatment type,
Hammill (2024)	SA	Cross-sectional study: Inj data collected bi-weekly using online inj questionnaire supported by qualified field workers. Risk factor data collected at beginning of season	Not Known 1 x season	University level. Total 17 players, 10 inj. Mean age 20.8 ± 1.4 y	All lower extremity injuries	10 lower extremity inj	Lower Limb	Age, ht, mass, body fat %, isokinetic knee strength, quadricep: hamstring ratio, inj side
Jolingana-Seoka et al. (2024)	SA	Cross-Sectional study: Self-report inj data collected bi-weekly via online questionnaire. Risk factor data collected pre-season	2022 1 x season	University level netball players. Total 10 players. Mean age 21.2 ± 1.4 y	All lower extremity injuries	Total unknown Proportion: 30% ankle, 20% foot, 20% back, 10% knee, 10% calf, 10% hip inj	Lower Limb	Ankle ROM, isokinetic strength, lower limb muscle activity, limb dominance

Note. AUS = Australia; NZ = New Zealand; SA = South Africa; Inj = injury/injuries; Comp = Competition; Physio = Physiotherapy/Physiotherapist; Champs = Championships; y = year; m = month; wk(s) = week(s); hrs = hours; mins = minutesU = Under; ht = height; wt = weight; BMI = body mass index; SD = standard deviation; CI = confidence interval; ACL = Anterior Cruciate Ligament; WASIS = Western Australian Sports Injury Study; CAI = Chronic Ankle Instability; CAIT-Y = Cumberland Ankle Instability Tool; SEBT = Star Excursion Balance Test: AIS = Australian Institute of Sport; AMS = Athlete Management System; ANZ = Australia and New Zealand premiership; ConQ:ConH ratio = concentric quadriceps: concentric hamstring ratio; ROM = range of motion

*Note***.** The term mechanism is retained from the original literature/published table and is interpreted in this thesis as referring to injury causation descriptors, including mechanism of onset and/or injury-inciting events (see Chapter 2).

studies more frequently utilised prospective study designs (n = 12, 63%). Similarly, most analytic studies (Table 3.3), were prospective in design (n = 11, 52%) with 7 (33%) using cross-sectional designs (Figure A1, Appendix A). One analytic study reported both retrospective and prospective injury data (Hopper & Elliott, 1993), hence a total of 22 analytic epidemiology study designs are reported.

3.3.2.2 Year of Publication. Eighteen descriptive epidemiology studies were conducted pre–2008 (41%), and 14% (n=6) of the descriptive studies reported data collected prior to 1998. Post-2018, eight hospital or clinic record studies (18%) and six netball competition studies (14%) have been conducted. Analytic research has increased considerably in the 15 years since 2008 (n = 15, 71%), with nearly half of these studies published since 2019. Table A2 (Appendix A) summarises the frequency of studies by publication year and study design. It is also important to note that the injury data reported in these studies were collected over periods ranging from one year (Purdam, 1987) to 16 years (Hume & Marshall, 1994) before publication.

3.3.2.3 Country of Origin. The studies presented in Tables 3.1–3.3 indicate that only eight of the 77 countries affiliated to World Netball have conducted published netball injury research (World Netball, 2024). Most studies were conducted in Australia (n = 32, 49%), New Zealand (n = 14, 22%) and South Africa (n = 11, 17%). Australian studies predominantly comprised both descriptive netball competition studies and analytic epidemiological investigations, while New Zealand research largely utilised hospital, clinic and insurance datasets. South African studies included a combination of descriptive netball competition and analytic designs. Only four studies (6%) were conducted in the UK, comprising hospital/clinic and insurance-based studies (Hassan & Dorani, 2001; Kirkwood et al., 2019; Mitchell et al., 2021), and a single analytic study (Mullally et al., 2023), with no netball competition studies identified to date. Figure A2 (Appendix A) summarises the distribution of studies by country of origin.

3.3.2.4 Data Collection Period. A wide range of data collection periods were used across the netball studies, with hospital/clinic and insurance datasets reporting the longest surveillance durations (Table 3.1). Most studies using these datasets collected data over four years or more (n = 14, 56%), while others reported data over one year (n = 9, 36%), two to three years (n = 3, 12%), or shorter periods.

Descriptive netball competition studies (Table 3.2) collected injury data during netball seasons (n = 8, 42%), netball tournaments (n = 6, 32%) or defined time periods (n = 5, 26%). Season-based studies ranged from single-season surveillance (e.g., 12–17 weeks) to multi-season designs, including school, state and club-level competitions. Tournament-based studies collected data over short durations (e.g., 3–10 days). Studies using defined time periods reported durations of four weeks, 12 months, one previous season, or up to five years.

Analytic studies (Table 3.3) similarly recorded injury data across seasons (n = 11, 52%), tournaments (n = 4, 19%) or specified time periods (n = 6, 29%). Season-based designs included state league surveillance and follow-up of injured players over one or two seasons. Other analytic studies reported injury data from multi-day tournaments or defined time periods ranging from the previous 12 months to 8.5 years.

3.3.2.5 Study Populations. The populations investigated across the netball injury studies showed considerable variation. Hospital/clinic and insurance studies (Table 3.1) included the largest populations, ranging from 3 to 11,757 participants. Sixty percent of these studies included more than 100 participants, and 40% included more than 1,000 participants. Most studies included a combination of children and adult age groups (60%), with children typically categorised as under 15 years. A smaller proportion of studies focused exclusively on adult populations (28%), defined as participants aged 15 years and older.

Netball competition studies (Table 3.2) analysing season-long competitions included populations ranging from 37 to 11,228 participants, with 56% (n = 5) including fewer than 300 participants. Within these season-long competition studies, populations comprised both adults and children in four studies and adults only in three studies, while several used typical netball age categories (under 18, under 19 and under 21). Studies assessing tournaments reported smaller populations ranging from 14 to 1,280, with half of studies including fewer than 200 participants. Tournament populations included both adult-only cohorts and mixed adult and junior age groups, spanning under-15 to under-21 and senior categories. The studies analysing defined time periods included populations ranging from 59 to 1,512 participants, with two studies including more than 1,000 participants. These populations encompassed junior and junior school players as well as mixed child and adult age groups, including under 16, under-21 and senior categories (Table 3.2).

The analytic studies reported the smallest populations (Table 3.3). Studies analysing seasons included cohorts ranging from 10 to 368 participants, with 81% comprising fewer than 100 adult participants. Tournament-based studies reported larger populations, ranging from 204 to 1,280 participants, however, most included less than 300 participants (75%), encompassing under 16, under 21 and Open (adult) players. Studies analysing defined time periods assessed populations of 16 to 536 athletes, typically involving fewer than 200 participants (67%). Two of these studies focused on ACL injury-inciting events in elite athletes (Belcher et al., 2022; Stuelcken et al., 2016).

3.3.2.6 Level of Competition. The hospital/clinic and insurance studies (Table 3.1) predominantly assessed the general population across all participation levels (68%) or netball populations across all levels of play (28%), with only one study specifically investigating elite netball (Purdam, 1987). In contrast, netball competition and analytic studies more frequently examined specific competition levels or combinations of levels (Tables 3.2 and 3.3). Netball competition studies assessed multiple levels of competition (32%), including combinations of elite and sub-elite, elite and recreational, and recreational to competitive levels. Other studies focused on players at specific levels including recreational or community (club) level, junior and senior school level, elite level, sub-elite level, recreational junior level and university level. The analytic studies similarly assessed a combination of elite and sub-elite levels (29%), recreational or community (club) level, university level and elite-level netballers. Among the studies conducted at the elite level, two analysed the ANZ Premiership (Belcher et al., 2022; Stuelcken et al., 2016), with one investigating the Netball World Cup (Janse van Rensburg et al., 2019), and one assessing the Suncorp Super Netball competition (Toohey et al., 2022).

3.3.2.7 Data Collection Methods. Data collection methods in the hospital, clinic and insurance studies all involved injury diagnosis by medical professionals. In contrast, the netball competition and analytic studies employed a wider range of data collection approaches (Tables 3.2 and 3.3; Figure A3, Appendix A). Injury data were collected via player self-reporting in 47% of netball competition studies and 38% of analytic studies. A combination of self-reporting and diagnosis by a medical professional, often involving the coach or team manager, was used in 32% of netball competition studies and 43% of analytic studies. Medical professionals alone, typically physiotherapists, diagnosed player injuries in 21% of netball competition studies and 19% of analytic studies. Data collection methods varied by level of competition, with medical professional diagnosis more commonly used at the elite level (80%) and self-reporting more frequently used at the recreational or community level (75%).

Across netball competition and analytic studies, only two studies captured longitudinal data for all injuries using ongoing, systematic injury surveillance systems (Tables 3.2 and 3.3). Toohey et al. (2022) reported standardised injury data from a cohort of elite players competing in the Suncorp Super Netball competition. This study assessed 119 players from eight teams across three seasons using a customised athlete management system developed by the Australian Institute of Sport. Horgan et al. (2021) similarly reported four years of retrospective injury data from the same centralised database in a cohort of 536 elite and pre-elite athletes.

3.3.2.8 Body Regions. Most netball injury studies assessed injuries across all body regions

(60%), as shown in Tables 3.1–3.3 and Figure A4 (Appendix A). The most commonly analysed specific body regions were the knee and the lower limb. Five hospital/clinic and insurance studies (20%) and two analytic studies focused, specifically on the knee. Lower limb injuries were examined in five analytic studies, with two further studies analysing combined lower limb and back injuries, and two focusing specifically on ankle injuries. Hospital, clinic and insurance studies also examined fractures across all body regions, as well as dental injuries and Achilles tendon injuries.

3.3.2.9 Injury Definitions. A wide range of injury definitions were used across the netball injury research, as summarised in Tables 3.1–3.3. Hospital, clinic and insurance studies (Table 3.1) most commonly applied medical attention definitions (44%), referring to injuries resulting in clinic or hospital attendance. A further 28% of studies used medical attention definitions related to specific injuries, including fractures, anterior cruciate ligament injuries and Achilles tendon injuries. The remaining studies (28%) defined injuries as any complaint resulting in an insurance claim, either for all injuries or for specific injury types such as dental or anterior cruciate ligament injuries.

Netball competition studies (Table 3.2) most frequently employed any or all complaints definitions (58%). Five of these studies used any complaints that impaired performance, three any complaints leading to medical attention and time-loss, and three used approved sports injury definitions. A further six studies (32%) applied medical attention definitions, two of which excluded minor injuries, while time-loss from training or competition definitions were used in two studies. The analytic studies (Table 3.3) similarly applied heterogeneous injury definitions, with all complaints definitions used in six studies (38%), while others applied medical attention, time-loss, or injury-specific definitions. A small proportion of studies identified injuries as new or recurrent (n = 11, 17%), with recurrent injuries most commonly defined as the same injury occurring following recovery from an index injury. Toohey et al. (2022) additionally defined subsequent injuries as any injury occurring after an initial injury within the defined surveillance period.

3.3.2.10 Injury Severity and Burden. Injury severity definitions were reported in 40% of the hospital/clinic and insurance studies (Table 3.1). Four studies used recognised injury severity scoring systems, while others reported severity based on the number or type of treatment received, or proxy measures such as injury cost or hospital admission and length of stay. Fourteen of the netball competition studies (56%) reported injury severity, of which 50% used time-loss from participation definitions. Other studies defined severity based on injury symptoms, level of treatment, combined treatment and time-loss, or pain ratings (Table 3.2). Similarly, among analytic epidemiology studies, 38% reported injury severity, most commonly using time-loss definitions or specific injury scoring tools (Tables 3.3). Across studies, severity was typically based on grades or categories, most commonly grades 1–3 or categories such as minor, moderate and severe. Only one study reported injury burden across the 65 included studies. Toohey et al. (2022) defined burden as the product of mean severity and injury incidence.

3.3.2.11 Injury Classifications. Injuries were typically classified across studies by body location or by a combination of injury location and type. Recognised injury classification systems were only used in nine studies (14%) (Tables 3.1–3.3). The International Classification of Diseases (ICD) (World Health Organization, 2019) was used in six hospital/clinic or insurance studies, while the OSIICS was used in one hospital/clinic or insurance study and two netball competition studies (Orchard et al., 2024). Injuries were additionally classified by the mode of onset (traumatic or overuse) in two hospital/clinic or insurance studies, seven netball competition studies and three analytic studies.

3.3.2.12 Injury Incidence Rates. Tables 3.1–3.3 show that a small number of studies reported only total injury counts, while others reported the proportion of injuries sustained. The remaining studies used a wide range of methods to report injury incidence rates. Hospital/clinic and insurance studies typically reported injury rates in relation to an actual or estimated population (n = 10, 40%), most commonly expressed as rates per 100,000 netball participants or 1,000 participants (Table 3.1). Netball competition studies most frequently reported injury rates per 1,000 player hours (47%). Other competition studies reported rates per 1,000 or 10,000 players, per player per season, per 1,000 players per match or per 365 player days, while two studies reported injury prevalence instead of incidence (Table 3.2). Among analytic studies, injury rates per 1,000 player hours were the most frequently used incidence metric (29%). Other analytic studies reported injuries per player, per 100 players per year, per player per year, daily injury probability, or injury prevalence (Table 3.3).

3.3.2.13 Athlete Exposure. A variety of methods were used to calculate injury incidence rates using athlete exposure hours (Tables 3.2–3.3). Most studies estimated match and/or training exposure based on the average duration of playing and training within the specified time period. Only two studies calculated exposure using individual match and training attendance records (Attenborough et al., 2017; Franettovich Smith et al., 2020). Of the netball competition studies reporting athlete exposure (53%), most used match exposure hours only, with others combining match and training hours. Exposure was calculated at the individual level in most studies, although some reported team-based exposure hours. Six analytic studies (29%) reported athlete exposure, including combined match and training hours in four studies and match-only exposure in two studies. Individual exposure hours were most frequently used, although two studies reported team-based exposure. Two further related studies from the same cohort calculated individual athlete exposure as match time in minutes prior to injury occurrence (Coetzee et al., 2014; Langeveld et al., 2012).

3.3.2.14 Injury Mechanisms (mechanism of onset and injury-inciting events). In this review, "injury mechanisms" is used as an umbrella term reflecting terminology in the included studies and is interpreted in accordance with Chapter 2 as referring to mechanism of onset and/or injury-inciting events. The mechanism of onset or event associated with injury was identified in seven (28%) of hospital/clinic or insurance record studies, typically using broad categories such as overexertion, falls and collisions. Eleven netball competition studies (58%) reported injury mechanisms, most commonly using questionnaire-based approaches with predefined response categories (e.g., Pringle et al., 1998; Sinclair et al., 2020). These included sharp twists or turns, falls, incorrect landing, collision with another player, trip or slip, being trodden on, sudden stopping, being struck by a player or ball, overexertion, or other reasons. Two netball competition studies provided more detailed descriptions of injury circumstances, including playing strategy (attack or defence), playing action (e.g. intercepting), and movement patterns (e.g. shuffling) at the time of injury (Hopper et al., 1995a; Hume & Steele, 2000). Eight analytic studies (38%) reported injury mechanism information as part of their injury analysis, with three further studies adopting a specific injury mechanism focus. This included studies examining injury situations in relation to previous injury history (Mullally et al., 2023). Two analytic studies assessed injury-inciting events using systematic video analysis methods, providing detailed descriptions of game situations, player movement patterns, player behaviour and qualitative biomechanical features of netball injuries to identify patterns in anterior cruciate ligament injury events (Stuelcken et al., 2016; Belcher et al., 2022).

3.3.2.15 Injury Risk Factors. The included studies assessed a wide range of intrinsic and extrinsic risk factors and their association with injury occurrence (Table A3, Appendix A). Hospital/clinic or insurance studies assessed the smallest number of risk factors per study (median = 1, range 0–7 factors), most commonly examining age, gender and cost of injury. Netball competition studies assessed a broader combination of risk factors (median = 4, range 0–11), with four studies analysing between 8 and 11 factors. The most frequently assessed intrinsic factors included age, playing position and previous injury, while common extrinsic factors included weekly training volume, initial treatment required, and match quarter in which the injury occurred.

Commensurate with their purpose, analytic studies assessed the widest range of risk factors (median = 6, range 3–15), with five studies examining between 10 and 15 factors

(Table 3.3 and Table A3, Appendix A). The intrinsic factors most frequently analysed included age, previous injury, height, body mass and playing position. A wide range of anatomical and biomechanical factors were also examined in 15 studies, including limb dominance, postural stability, podiatric variables, ankle joint laxity and range of motion, and lower body stiffness. Physiological factors such as aerobic and anaerobic fitness, agility, strength, power, speed and flexibility were additionally assessed across seven studies. Extrinsic risk factors included level of competition and match quarter, with a wide range of timing-, training- and treatment-related factors also examined across the analytic studies.

3.3.2.16 Data Analysis Methods. A range of descriptive and inferential statistical approaches were used across the included studies to analyse injury datasets (Figure 3.2). More than 40% of the hospital/clinic and insurance records and netball competition studies reported descriptive statistics only. A small number of studies additionally reported effect estimates such as odds ratios, risk ratios or injury incidence rate ratios to describe differences between groups. Univariate inferential statistics were additionally used to assess associations between risk factors and injury occurrence in 60% of hospital/clinic and insurance record studies and 53% of the netball competition studies. The chi-square test was the most frequent univariate test used in the descriptive epidemiology studies (76%). Multivariate statistical analyses were uncommon in these studies, with only Fernando et al. (2018) using binary logistic regression models and Toohey et al. (2022) applying generalised linear mixed models.

Most analytic studies used inferential statistics to assess the effect of risk factors on injury occurrence (81%). Five studies reported odds ratios, while other studies reported risk ratios, absolute risk and injury incidence rate ratios. Univariate statistics, including chi-square, t-tests, Mann-Whitney U tests, analysis of variance and univariate logistic regression, were used in 76% of studies. Only five (24%) studies used multivariate approaches, most commonly multiple logistic regression models, with adjustments for confounding variables conducted in three studies. The three studies focusing on injury causation provided descriptive analyses only (Stuelcken et al., 2016; Belcher et al., 2022; Mullally et al., 2023).

3.4 Discussion

This scoping review presents the first comprehensive overview of research methodologies used to determine injury incidence, aetiology, and causation in netball. It complements the recent reviews of netball injury research by Downs et al. (2021) and Whitehead et al. (2021), highlighting methodological considerations aligned with the first two steps of the van Mechelen et al (1992) and TRIPP (Finch, 2006) injury prevention models. A total of 65 netball injury studies were included following screening, consisting of 44 descriptive epidemiological studies and 21 analytic epidemiological studies. The review highlights a scarcity of studies using systematic and ongoing injury surveillance, as well as limited methodological approaches to assess injury aetiology and causation in netball. Without a specific consensus statement for netball to guide injury research, this review proposes potential future directions to enhance the quality of the netball injury evidence base.

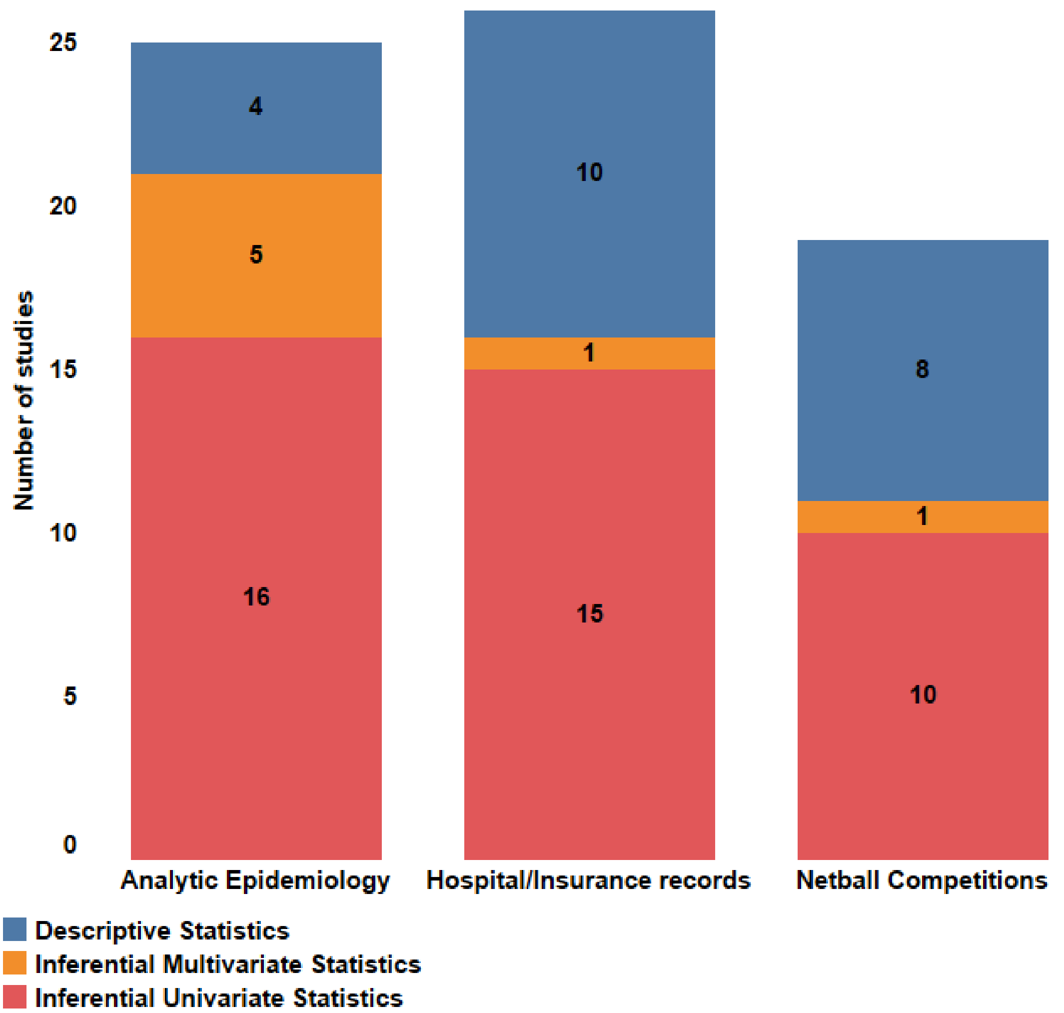

Figure 3.2 *Frequency of Netball injury studies by study design and data analysis methods*

The extent of the injury problem in netball is described in the 44 descriptive epidemiological studies and 19 (90%) of the analytic studies reporting injury data. However, 41% of descriptive studies and 29% of analytic studies were published between 1986 to 2008, with injury data collected an average of 3.6 years prior to publication. Furthermore, the majority of netball injury research has been conducted in Southern Hemisphere countries (88%), predominantly Australia (49%), and thus does not represent all netball-playing nations. Recent advancements in injury data collection methods [94], together with the growing professionalisation of netball with its increased physical demands (Whitehead et al., 2021; van Gogh et al., 2020), and variations in playing styles across countries (World Netball, 2024) emphasise the need for further research. This should encompass the diverse range of playing nations to fully understand the injury problem in line with the demands of the modern game.

The netball injury research has utilised various data sources, including hospital, clinic, and insurance databases (39%), as well as different competition formats, and specified time periods (descriptive epidemiology 29%; analytic epidemiology 32%). While hospital/clinic or insurance studies, utilise large populations and longitudinal data (Joseph et al., 2019), they primarily capture severe injuries (Ekergen et al., 2016; Downs et al., 2021), thereby underestimating injury incidence by neglecting milder cases. In contrast, data from netball competitions capture a broader range of injuries, providing a more accurate portrayal of the sport's injury problems. Yet, studies vary considerably in observation periods, including short tournaments of 3–10 days (25%), league competitions over single or multiple seasons (50%), or specified time periods (25%). The lack of netball injury studies reporting longitudinal data from ongoing, systematic injury surveillance systems is a key finding of this study. Ekergen et al. (2016) emphasised the need for such systems to provide high-quality data for effective injury prevention. However, only two (3%) netball studies report injury data from "true" injury surveillance systems. Toohey et al. (2022) collected injury data from a prospective cohort, in the elite Suncorp Netball Superleague over three consecutive seasons, using standardised methods [94]. While Horgan et al. (2021) assessed retrospective data from the same centralised database (AMS), to assess the impact of risk factors on previously recorded injuries. The lack of comprehensive injury surveillance impacts the accuracy and reliability of the current netball injury research.

The current netball injury studies employed diverse methodologies to collect injury data, utilising prospective, retrospective and cross-sectional designs across the study categories. Study populations included a broad range of netball participants ranging from 3 (Hon & Kock, 2001) to 11,757 (King et al., 2019c), with many including a combination of age-groups and participation levels, often lacking clear definitions. Indeed, Ferreira & Spamer (2010) defined "elite" netballers as University first team players, while Janse van Rensburg (2021) defined "elite" as those representing their country at the 2019 Netball World Cup. Injury diagnosis methods also differed, hospital/clinic or insurance studies using medical professionals, while competition studies used mostly medical staff at the elite level (80%) and self-report methods at the community/recreational level (75%).

Injury definitions varied across injury studies, with hospital/clinic or insurance studies mainly employing medical attention definitions (72%), while competition and analytic studies used a broader range, including all complaints (51%), medical attention (30%) and time-loss definitions (19%). Definitions of injury severity also varied, incorporating time-loss, treatment, symptom, hospital attendance and cost of injury criteria. To date, Toohey at al. (2022) is the only study to report injury burden, a critical measure that combines injury frequency with its severity (typically measured in days lost) (Bahr et al., 2020). This metric allows for the identification of not only the most common injuries but also those that impose the greatest impact (Bahr et al., 2018). This understanding is vital for comprehensively assessing the repercussions of injuries within netball. Furthermore, only a small number of studies defined recurrent injuries, (14%) or used a recognized classification system for injuries (14%).

These variations in study design and data collection methods make it difficult to compare netball injury studies and differentiate injury risks within defined populations. The methodological issues subsequently impact the reported incidence rates in the current netball injury research. Moreover, the different metrics for calculating injury incidence further confuse the extent of the injury problem. Although several netball competition studies (Botha et al., 2020; Finch et al., 2002; Hume & Steele, 2000; Janse van Rensburg et al., 2021; Langeveld et al., 2012; Pringle et al., 1998; Sinclair et al., 2020; Smyth et al., 2019; Stevenson et al., 2000) and analytic studies (McManus et al., 2006; Franettovich Smith et al., 2020; Coetzee et al., 2014; Attenborough et al., 2017; Pickering Rodriguez et al., 2017; Belcher et al., 2022) report injuries in relation to athlete exposure hours, differences in exposure calculation methods, including use of match hours only, combined match and training hours, and average team or individual hours, have also impacted reported incidence rates. This has led to incidence rates ranging from 11.3 to 89.4 injuries/1000 player hours (Table 3.1–3.3). Additionally, two studies (Langeveld et al., 2012; Coetzee et al., 2014) calculated player exposure based on game time in minutes prior to injury rather than total exposure time accumulated over the study period, resulting in an extremely high injury incidence rate of 500.7 injuries per 1000 hours.

To develop a clear understanding of the injury problem (van Mechelen et al, 1992; Finch, 2006), robust injury surveillance systems are crucial for netball to ensure accurate data informs the evidence base. The England Rugby Football Union (RFU), has effectively implemented such systems across elite men's and women's levels (PRISP and WRISP projects), community level (CRISP project) and university level (BUCS ISP project) (England Rugby, n.d.) providing an effective model for netball. Currently, no netball injury research has assessed the UK Netball Superleague, or New Zealand ANZ Premiership, and only one study assesses the Australian Suncorp Super Netball. Therefore, future research should focus on the development of robust surveillance systems to provide consistent injury data to analyse all competitions at the elite level. Furthermore, there is a need to develop tailored surveillance systems for all levels of the game.

This study recommends adopting the standardised methods of data collection in the International Olympic Committee (IOC) consensus statement (Bahr et al., 2020) to ensure consistent surveillance methods. This updates the recommendations of Downs et al. (2021), who endorsed the rugby union consensus statement (Fuller et al., 2007). The guidelines include consistent use of either all complaints, medical attention or time-loss injury definitions, and time-loss severity definitions, depending on the study focus. They suggest using measures of injury burden that combine frequency and consequences, typically injury incidence multiplied by severity (time-loss days). Recommendations for classifying injuries are provided using consistent coding systems such as the Orchard Sports Injury and Illnesses Classification System (OSIICS) (Orchard et al., 2024). Furthermore, to standardise the reporting of injury rates, the IOC statement recommends recording individual player exposure hours and expressing injury incidence rates per 1000 athlete exposure hours for sudden-onset injuries. For gradual-onset conditions, it suggests reporting prevalence as the proportion of injured athletes (Bahr et al., 2020).

In addition to the IOC guidelines, this study recommends incorporating netball-specific demographic categories to define study populations. Age categories such as Senior/Adult, under 21, under 19, under 17, and Junior levels such as Under 16, Under 15, Under 14 are consistently used across nations in international, national, and school-level competitions, providing a consistent and widely applicable framework. Reporting the mean age and age range in each category would further enhance the description of population age characteristics. To describe level of play, it is recommended that netball populations are classified according to Mckay et al.'s. (2021) skill level and training status framework, which categorises participants across five tiers (Tier 0–4): sedentary, recreationally active, trained/developmental, highly trained/national level, and elite/international level. Within this framework, elite/international netball would include all international competitions and elite domestic leagues such as the UK Netball Superleague, Australia's Suncorp Super Netball, and New Zealand's ANZ Premiership. Consistent reporting of injuries using these standardised categories would improve clarity and comparability of injury data across netball populations and playing standards. A summary of the recommended guidelines for identifying the injury problem in netball, is provided in Figure 3.3.

The current research assessing injury aetiology in netball has notable limitations. Twenty-one analytical studies aimed to identify the risk factors associated with injury occurrence, while a further 34 descriptive studies investigated isolated factors related to injury. Collectively, these studies have assessed a wide range of intrinsic and extrinsic risk factors, but typically only a small combination of factors within each study. Specifically, the analytic studies analysed a median of 6 risk factors across the 21 papers. Furthermore, most studies employed a reductionist approach, simplifying factors into units in a linear, unidirectional way. This approach is thought to restrict understanding of injury aetiology, particularly where interactions between multiple factors may determine injury potential (Bahr & Holme, 2003; Bittencourt et al., 2016). Only 11% of the netball studies used multivariate statistics to assess the impact of a range of risk factors on injury, and even these approaches are suggested to be insufficient to identify the complex interactions between multiple risk factors (Bittencourt et al., 2016).

The inciting event leading to an injury has been identified in a number of netball injury studies using a range of methods. Some studies report the mode of injury onset as acute or overuse and/or classify the mechanism of onset as contact/non-contact. A larger proportion of studies (45%) describe the injury-inciting event using athlete self-report or medical staff report, typically guided by basic predefined response categories. While this approach has provided some valuable descriptive information, it offers only a simplified account of the injury event and is often limited in accuracy, as it relies on retrospective recall that may be subject to bias (Krosshaug et al., 2005). Consequently, understanding of injury-inciting events in netball remains limited. To date, only two studies have examined these events in greater depth using video-based methods. Stuelcken et al. (2016) and Belcher et al. (2022) integrated situational, behavioural and biomechanical descriptors to characterise anterior cruciate ligament injury-inciting events, providing a more comprehensive account of how injuries occur. However, no research to date has developed video-based methods to assess a wider range of injuries and their inciting events in netball.

To better understand the aetiology of injury (the underlying risk structure) and its causation (injury-inciting event), in the second step of the sequence of injury prevention (van Mechelen et al., 1992; Finch, 2006), research should employ a multifactorial approach. This should assess the complex interaction between multiple intrinsic and extrinsic factors, workload and the injury-inciting event (Bahr & Holme, 2003; Windt & Gabbett, 2017). Hence, studies need to make use of a dynamic model which describes the interaction between as many risk factors as possible, appropriate workload measures and the events leading to the injury. The multifactorial model additionally needs to account for the dynamic, recursive nature of sports injury. Such models include Windt & Gabbett's (2017) workload-injury aetiology model, developed from the original multifactorial models of Meeuwisse and colleagues (Meeuwisse, 1994; Meeuwisse et al., 2007). Accurate assessment of netball injury-inciting events, to inform the injury model, require a consistent approach. The development of video-based methods that fully describe the playing situation, player/opponent behaviour and accurately assess the biomechanics of injury are necessary to provide a complete assessment of the injury- inciting event. Combining these video methods, where possible, with athlete and medical staff descriptions is recommended to provide a more comprehensive understanding of injury causality (Bahr & Krosshaug., 2005; Krosshaug et al., 2005). To facilitate clear comparisons between studies, the definitions and terminology recommended in the recent consensus on netball video analysis framework (Mackay et al., 2023) should also be adopted.

Finally, to analyse the non-linear interactions between these injury determinants a complex systems approach has been suggested by Bittencourt et al. (2016) to be a more appropriate method of assessing sports injuries. The method identifies a risk profile from the interactions between the “web” of injury determinants. Appropriate statistical methods are necessary to support injury prediction, rather than only estimating relationships. These methods include recursive partitioning-based methods e.g. classification and regression trees (CART) and random forests, or machine/statistical learning methods (Bittencourt et al., (2016). Figure 3.3 summarises the recommendations for netball injury aetiology and causation research methodologies. Future research should address these methodological concerns to provide an accurate netball injury evidence base which is critical to inform the development of targeted injury prevention strategies. This study provides a comprehensive summary of the research methodologies describing the extent of the injury problem and aetiology and causation of injuries in netball. However, it is possible the search may not have identified all studies in the area.

3.5 Conclusion

This scoping review reveals a lack of systematic and ongoing injury surveillance systems in the netball injury research describing the injury problem. Studies exhibit considerable heterogeneity in methodologies, including study designs, injury definitions, data collection methods and injury reporting practices. Inconsistent methods of reporting injury rates and classification of study populations further limit the quality of evidence across different age groups and level of play. Research assessing injury aetiology often focuses on a limited number of risk factors, using reductionist approaches, while studies assessing injury causation often use simplistic descriptions, based on unreliable retrospective recall. Therefore, additional research is needed to comprehensively assess the netball injury problem, its aetiology and causation within the modern game, considering a broader spectrum of playing styles.

Figure 3.3 *Netball injury research methodological recommendations*

Accurately identifying key injury issues in netball, requires reliable and consistent injury surveillance systems across settings. The IOC consensus statement guidelines are recommended for the accurate collection of injury data, providing clear definitions, collection methods and reporting protocols. To understand the aetiology and causation of netball injuries, a multifactorial approach is essential to assess the complex interaction between multiple intrinsic and extrinsic factors, player load and the injury-inciting event. Detailed assessment of the injury-inciting event should encompass the playing situation, player/opponent behaviour, and joint and whole-body biomechanics utilising video analysis and medical staff descriptions.

Chapter 4: Match and Training Injury Epidemiology in Elite UK Netball: A Prospective Cohort Study over One Season

This chapter presents a prospective cohort study describing injury incidence, severity and burden in the Vitality Netball Superleague, originally published in *BMJ Open Sport & Exercise Medicine* (Horne et al., 2025; see also p. v for publication details). The study addresses key methodological gaps identified in Chapters 2 and 3 by implementing a systematic injury surveillance approach aligned with contemporary recommendations and provides the epidemiological context for the injury-inciting event analyses presented in Chapters 5 and 6.

4.1 Introduction

Netball is a predominantly female sport with over 20 million participants worldwide and continues to grow in global popularity (World Netball, 2024). The sport is characterised by its fast competitive nature, repeated dynamic movements, and the restrictive footwork rule, which together impose considerable forces and workloads on players (Brooks et al., 2020b; Davidson & Trewartha, 2008; Fox et al., 2013; Steele, 1990; Stuelcken et al., 2013; Young et al., 2016). These demands are reflected in high reported injury rates ranging from 11.3 to 500.7 injuries/1000 player hours across studies (Finch et al., 2002; Langeveld et al., 2012). Across the literature, lower limb injuries are most frequently reported, particularly ankle and knee ligament injuries (Hopper et al., 1995a; Hume & Steele, 2000; Janse van Rensburg et al., 2021; Langeveld et al., 2012; Smyth et al., 2020; Toohey et al., 2022). These injuries commonly occur during landing actions or following player contact (Hopper et al., 1995a; Hume & Steele, 2000; Smyth et al., 2020; Toohey et al., 2022). However, the absence of systematic and standardised injury surveillance in netball has limited the clarity, comparability, and practical utility of the existing evidence base for informing injury prevention strategies (Ekegren et al., 2016; Horne et al., 2024).

Current netball injury studies vary widely in designs, injury definitions, data collection methods and reporting practices, with many earlier studies no longer reflecting the physical demands, speed and professionalisation of the modern game (Horne et al., 2024; Downs et al., 2021; Whitehead et al., 2021). To date, only two studies conducted at the elite international or professional level have adhered to recent international methodological guidelines for sports injury surveillance (Bahr et al., 2020), examining injuries sustained during the 2019 Netball World Cup (Janse van Rensburg et al., 2021) and Australia's Suncorp Super Netball (SSN) competition (Toohey et al., 2022). Of these, only the latter employed an ongoing, systematic injury surveillance system across a full competitive season

(Horne et al., 2024). While both studies reported high rates of match-related ankle and knee injuries, neither provided comprehensive data on training injuries. Consequently, it remains unclear whether injury incidence, characteristics and burden differ between match and training exposures in elite netball. Furthermore, no comparable injury surveillance data currently exist for the UK's elite Vitality Netball Superleague (VNSL), representing a significant gap in the evidence base. Therefore, this prospective cohort study implemented robust injury surveillance methods to describe the incidence, types, mode of onset, mechanism of onset, and impact of match and training injuries during a competitive VNSL season (including pre-season, in-season and post-season) lasting 14 months.

4.2 Methodology

4.2.1 Pilot study and evolution of the VNSL injury surveillance system

An initial injury analysis was conducted during the 2019 VNSL using modified competition injury documentation informed by contemporary surveillance recommendations to prospectively capture player exposure and injury data. Although participation and data completeness were limited, the pilot identified practical challenges in injury reporting, particularly variability in compliance and data capture. These findings demonstrated the need for a standardised, centrally managed system and directly informed subsequent developments to the competition's surveillance process. As a result, England Netball introduced mandatory injury reporting using the Performance Data Management System (PDMS), developed by the English Institute of Sport (Leaders Performance Institute, 2020). Following cancellation of the 2020 season due to the COVID-19 pandemic, the PDMS-based system was implemented prospectively in the 2021 VNSL competition.

4.2.2 Study design and setting

A prospective cohort design assessed all injuries during the 2021 VNSL season, lasting 14 months. This included pre-season preparation (1 September 2020–12 February 2021), in-season (12 February–27 June) and post-season follow-ups (4 months). COVID-19 protocols condensed the competition (in-season) to 20 rounds, two semi-finals, 3rd/4th play-off and a grand final over 16 weeks. Five weekends included two rounds played over 4 days (double-headers), and matches were reduced from 15-minute to 12-minute quarters. Injury recording followed the International Olympic Committee (IOC) consensus statement and STROBE-SIIS guidelines (Bahr et al., 2020). England Netball supported recruitment across participating teams, with findings disseminated to stakeholders via reports and conference presentations.

4.2.3 Participants

All players contracted to an English VNSL team in 2021 were invited to participate in the study. Nine English teams took part, comprising squads of 14–18 players, with 12 players selected per match (total population n = 137). Squads were predominantly English, with a small proportion of players from Northern Ireland and Wales (≈90%), and the remaining players originating from Australia, New Zealand, Jamaica, Malawi, and Uganda (≈10%), reflecting the diverse backgrounds represented within the league. Permission to conduct the research was granted by England Netball, and ethical approval was obtained from the Brunel University, College of Health, Medicine and Life Sciences Research Ethics Committee (Ref: 12619-MHR-Nov/2019-21150-1). Team gatekeeper consent and individual written informed consent were obtained from all participants following provision of study information, with parental or legal guardian consent additionally obtained for players aged 16–18 years. Documentation relating to ethical approval, organisational permission from England Netball, and participant consent material is provided in Appendix B (B1–B4).

4.2.4 Data collection

Medical attention, time-loss, and match and training injuries were diagnosed, treated, and recorded on the PDMS by VNSL team physiotherapists. New and subsequent injuries (Hamilton et al., 2011), excluding pre-existing injuries and exacerbations, were classified using the OSIICS v14 (Orchard et al., 2022). Injuries were categorised by mode of onset (acute or overuse), mechanism of onset (contact/non-contact; sudden/gradual onset), and severity (based on four categories of days lost (TL): 0, 1–7, 8–28 or >28 days). In this study, mechanism of onset variables were recorded in accordance with the IOC consensus statement and reflect broad surveillance classifications (e.g., contact/non-contact; sudden/gradual onset), rather than detailed analyses of injury-inciting events or biomechanical mechanisms. Injury impact was further described using medical attention days (MA), restricted days (RD), and overall duration (RD + TL). Injury frequency by playing position and month was also recorded. Full study definitions are in Table B1 (Appendix B).

4.2.5 Data analysis

4.2.5.1 Data quality. The quality of injury data recorded within the PDMS was evaluated using indicators of completeness and reliability, consistent with recommended approaches for injury surveillance research (Bahr et al., 2020). Data validity could not be formally assessed, as no independent “gold-standard” injury record was available for comparison (Ekergen et al., 2016). Injury reporting response rate was calculated as the percentage of teams that recorded at least one injury within the PDMS system relative to the total number of participating teams. Data completeness was quantified as the proportion of completed data fields relative to the total number of expected fields across all injury reports (Edouard et al., 2016). The reliability of injury reporting across VNSL teams was assessed by examining between-team variability in injury incidence rates, expressed as the percentage coefficient of variation (%CV), with lower variability indicating more consistent reporting practices across teams (Cross et al., 2018).

4.2.5.2 VNSL Injury data analysis. Match exposure was calculated as the proportionate player hours per match (consenting players/total players × 7 players) × matches played (round matches + semi-finals and finals). Training exposure was calculated as consenting players × mean training hours/week × training weeks. Incidence rates were calculated as the number of injuries/exposure hours × 1000. The Wilson Score interval with continuity correction was used to calculate 95% confidence intervals (CI) for injury incidence estimates where counts were low. This approach provides more accurate interval estimates for low event counts than normal approximation methods (Newcombe, 1998). Injury TL burden (TL burden) was calculated as mean severity (TL per injury) × injury incidence rate (Bahr et al., 2020; Fuller et al., 2023). For non-time loss injuries, the burden was calculated using mean medical attention days as the indicator of severity (MA burden).

Descriptive data are presented separately for matches and training exposures, with injury frequency calculated as the percentage (%) of total injuries, excluding missing data. Differences in injury distributions between match and training settings were examined using chi-square tests, applied where expected cell counts met recommended assumptions (≥5) (Janse van Rensburg et al., 2021). Statistical significance was set at $P < 0.05$, with Bonferroni correction applied to post hoc comparisons when significance was established. All statistical analyses were conducted in SPSS (Version 29.0.1.0 (171), IBM Corp., USA) and were guided by the Checklist for the Statistical Assessment of Medical Papers (CHAMP) (Mansournia et al., 2021).

4.3 Results

4.3.1 Study participants

Ninety players from seven English teams agreed to participate in the study (mean age 24.4 years; 95%CI: 23.4–25.4, mean height 179.3 cm; 95%CI: 177. 6–181.1). The participants represented 65.7% of the total English team population (n = 137) and 83.3% of the seven consenting teams (n = 108).

4.3.2 Data quality

Seven of the nine English teams provided study consent (77.8%), with a 100% injury-reporting response rate and 97.8% data completeness. Four teams provided training exposure data (57.1%), with low between-team variability (11.9% CV percentage). However, match (80.8%) and training (93.6%) incidence rates showed high variability, ranging from 8.2 to 106.9 injuries/1000 hours in matches and 0.2 to 3.1 injuries/1000 hours in training.

4.3.3 Epidemiology of Injury in the VNSL 2021

Seventy injuries (matches: n = 35; training: n = 35) occurred in thirty-nine players, representing a period prevalence of 43.3%. Match player hours were 851.18, resulting in an incidence rate of 41.12 injuries/1000 hours (95%CI: 29.22–57.32), while training hours were 31,888, resulting in an incidence of 1.10 injuries/1000 hours (95%CI: 0.76–1.54). Consequently, match injuries were 37.4 times more frequent than training injuries (95%CI: 23.45–59.85).

4.3.3.1 Injury mode of onset, mechanism of onset, impact, severity, and burden. Acute injuries were more frequent in matches (n = 27; 39.7% vs. n = 17; 25%), while incidences due to overuse injuries were higher in training (n = 18; 26.5% vs. n = 3; 4.4%; $p = 0.001$). Contact injuries were more frequently reported in matches (n = 21; 30.9% vs. n = 7; 10.3%), whereas non-contact injuries were more frequent in training (n = 10; 14.7% vs. n = 6; 8.8%; $p = 0.03$). Three match injuries (4.4%) were recurrent. No differences in injury impact (TL, RD, MA, and ID) were observed ($p > 0.05$). Severe injuries (>28 days) were more frequent in matches (n = 6; TL total 585, median 80 days versus n = 2; TL total 380, median 190 days) (Table 4.1). Match injury burden was higher, with greater total TL burden (762.5 days lost/1000 hours; 95%CI: 727.50–794.40) and MA burden (1465.1; 95%CI: 1391.03–1542.10), compared to training (TL: 13.7; 95%CI: 5.44–31.50 and MA: 29.5; 95%CI: 20.02–42.99).

4.3.3.2 Body region, body area and clinical diagnosis. The lower limb sustained the most injuries in matches (n=27; 38.6%) and training (n=25; 35.7%). In matches, ankle lateral ligament sprains were most common (n = 15; 21%), including four severe injuries (>28 days). Lower leg tendinopathy predominated in training (n=10; 14.3%), primarily affecting the Achilles tendon (n = 5; 50%), but without TL. Knee injuries were second most common in matches (n = 4; 5.7%) and third in training (n = 5; 7.1%), including two ACL injuries causing >28 TL. Five concussions were reported (matches: n = 2, training: n = 3), with the two match concussions leading to 8-28 TL days (Table 4.2). Ligament/joint capsule injuries were most common in matches (n = 16, 22.9%), while muscle/tendon injuries dominated in training (n = 18, 25.7%) (see Table B2, Appendix B).

Figure 4.1 shows the mode and impact of lower limb injuries, in relation to the total injuries in each category, for matches and training. All match ankle injuries were acute, mostly contact-related (n = 10; 66.7%), causing considerable TL (350 days; median 47 IQR 5–108). Training lower leg injuries were all overuse, resulting in no TL but substantial MA (439 days; median 30 IQR 22–71). A range of acute and overuse knee injuries were observed, including two acute, non-contact ACL injuries (match: n = 1; TL 208 days; training: n = 1; TL 288). Table B3 (Appendix B) details the impact of injuries by body region, area, and

Table 4.1 *Summary of match and training injuries by mode of onset, mechanism of onset, impact, and severity*

Injury Characteristic	Match Injuries				Training Injuries				*P* value
	No. of injuries (%)	**I (95%CI)**	**Total days Lost**	**Days Lost m (IQR)**	**No. of injuries (%)**	**I (95%CI)**	**Total days Lost**	**Days Lost m (IQR)**	
Total Injuries	**35 (50%)**	**41.12 (29.22–57.32)**	**649**	**47 (15–108)**	**35 (50%)**	**1.10 (0.76–1.54)**	**422**	**16.5 (5–144)**	
Mode									**0.001†**
Acute	27 (39.7)	31.72 (21.41–46.45)	649	47 (15–108)	17 (25.0)	0.53 (0.32–0.87)	422	16.5 (5–144)	
Overuse	3 (4.4)	*	0	0	18 (26.5)	0.56 (0.35–0.91)	0	0	
Recurrent	3 (4.4)	*	0	0	0	*	0	0	
Mechanism									**0.028†**
Contact	21 (30.8)	24.67 (15.72–38.12)	321	24 (10–51)	7 (10.3)	0.22 (0.10–0.47)	28	0 (0–0) *	
Non-contact	6 (8.8)	7.05 (2.87–16.09)	328	164 *	10 (14.7)	0.31 (0.16–0.60)	394	5 (5–190)	
Gradual onset	2 (2.9)	*	0	0	9 (13.2)	0.28 (0.14–0.56)	0	0	
Sudden onset	1 (1.5)	*	0	0	9 (13.2)	0.28 (0.14–0.56)	0	0	
Impact									
TL	11 (16.7)	12.92 (6.81–23.73)	649	47 (15–108)	6 (9.1)	0.19 (0.08–0.43)	422	17 (5–144)	0.120
RD	12 (18.2)	14.10 (7.66–25.22)	145	5 (2–11)	12 (18.2)	0.38 (0.20–0.68)	200	9 (7-27)	0.852
MA	21 (31.8)	24.67 (15.72–38.12)	1247	18 (6–90)	26 (39.4)	0.82 (0.54–1.21)	941	31 (11–47)	0.331
ID	17 (25.8)	19.97 (12.05–32.46)	794	19 (6–51)	16 (24.2)	0.50 (0.30–0.83)	622	9 (11-34)	0.622
Severity									
0 days	21 (31.8)	24.67 (15.72–38.12)	0	0	28 (42.4)	0.88 (0.59–1.29)	0	0	
1-7 days	2 (3.0)	*	6	3 *	3 (4.6)	*	14	5 *	
8-28 days	3 (4.6)	*	58	19 *	1 (1.5)	*	28	28 *	
> 28 days	6 (9.1)	7.05 (2.87–16.09)	585	80 (49–142)	2 (3.0)	*	380	190 *	

Note. Number of injuries & (%): frequency of total injuries, excluding missing data. I: incidence per 1000 player-hours. 95% CI = 95% Confidence Intervals. Days lost = Total days, m: median and IQR: interquartile range. Impact: TL = Time-loss days, RD = restricted days, MA = medical attention days. ID=Impact duration = time-loss days + restricted days.
* Incidence rates were calculated only for categories with ≥5 injuries. Median and IQR values were reported only for categories with ≥4 injuries. Mode/mechanism data missing: match n = 2. Impact/severity data missing: match n = 3, training n = 1. Recurrent match injuries (n = 3) are reported separately but included in injury frequencies. Chi-square tests excluded missing and recurrent injuries. † Significant activity-by-mode and activity-by-mechanism differences.

Table 4.2 *Distribution of match and training injuries by body region, area, clinical diagnosis and severity*

Body Region **Body area** Pathology Type	**Match Injuries**						**Training Injuries**					
	No. of injuries (%)	**I (95%CI)**	**0 days lost**	**1-7 days lost**	**8-28 days lost**	**>28 days lost**	**No. of injuries (%)**	**I (95%CI)**	**0 days lost**	**1-7 days lost**	**8-28 days lost**	**>28 days lost**
Head & Neck	**2 (2.9)**	*	**0**	**0**	**2**	**0**	**4 (5.7)**	*	**4**	**0**	**0**	**0**
Head	2 (2.9)	*	0	0	2	0	4 (5.7)	*	4	0	0	0
Brain/Spinal cord	2 (2.9)	*	0	0	2	0	3 (4.3)	*	3	0	0	0
Contusion	0						1 (1.4)	*	1	0	0	0
Upper Limb	**3 (4.3)**	*	**2**	**0**	**0**	**1**	**3 (4.3)**	*	**3**	**0**	**0**	**0**
Shoulder	1 (1.4)	*	1	0	0	0	2 (2.9)	*	2	0	0	0
Synovitis/ Capsulitis	1 (1.4)	*	1	0	0	0	1 (1.4)	*	1	0	0	0
Contusion	0						1 (1.4)	*	1	0	0	0
Forearm	1 (1.4)	*	0	0	0	1	0					
Fracture	1 (1.4)	*	0	0	0	1	0					
Hand	1 (1.4)	*	1	0	0	0	1 (1.4)	*	1	0	0	0
Fracture	1 (1.4)	*	1	0	0	0	0					
Synovitis/ Capsulitis	0						1 (1.4)	*	1	0	0	0
Trunk	**3 (4.3)**	*	**3**	**0**	**0**	**0**	**3 (4.3)**	*	**2**	**1**	**0**	**0**
Chest	0						1 (1.4)	*	0	1	0	0
Muscle injury	0						1 (1.4)	*	0	1	0	0
Thoracic spine	0						1 (1.4)	*	1	0	0	0
Joint sprain	0						1 (1.4)	*	1	0	0	0
Lumbar spine	3 (4.3)	*	3	0	0	0	1 (1.4)	*	1	0	0	0
Nerve injury	1 (1.4)	*	1	0	0	0	0					
Arthritis	2 (2.9)	*	2	0	0	0	1 (1.4)	*	1	0	0	0

Lower Limb	**27 (38.6)**	**31.72 (21.41–46.45)**	**16**	**2**	**1**	**5**	**25 (35.7)**	**0.78 (0.52–1.17)**	**19**	**2**	**1**	**2**
Hip/Groin	1 (1.4)	*	1	0	0	0	0					
Abrasion	1 (1.4)	*	1	0	0	0	0					
Thigh	4 (5.7)	*	4	0	0	0	1 (1.4)	*	0	1	0	0
Muscle injury	1 (1.4)	*	1	0	0	0	1 (1.4)	*	0	1	0	0
Muscle contusion	2 (2.9)	*	2	0	0	0	0					
Vascular trauma	1 (1.4)	*	1	0	0	0	0					
Knee	4 (5.7)	*	3	0	0	1	5 (7.1)	0.16 (0.06–0.39)	3	1	0	1
Laceration	1 (1.4)	*	1	0	0	0	0					
Tendinopathy	1 (1.4)	*	1	0	0	0	3 (4.3)	*	3	0	0	0
Cartilage injury	1 (1.4)	*	1	0	0	0	0					
Synovitis/ Capsulitis	0						1 (1.4)	*	0	1	0	0
Joint Sprain	1 (1.4)	*	0	0	0	1	1 (1.4)	*	0	0	0	1
Lower leg	2 (2.9)	*	2	0	0	0	10 (14.3)	0.31	10	0	0	0
Tendinopathy	2 (2.9)	*	2	0	0	0	10 (14.3)	(0.16–0.59)	10	0	0	0
Ankle	15 (21.4)	17.62	5	2	1	4	6 (8.6)	0.19 (0.08–0.43)	3	0	1	1
Joint Sprain	15 (21.4)	(10.26–29.59)	5	2	1	4	4 (5.7)	*	1	0	1	1
Tendinopathy	0						1 (1.4)	*	1	0	0	0
Muscle contusion	0						1 (1.4)	*	1	0	0	0
Foot	1 (1.4)	*	1	0	0	0	3 (4.3)	*	3	0	0	0
Bone	0						2 (3.0)	*	2	0	0	0
Tendinopathy	0						1 (1.4)	*	1	0	0	0
Abrasion	1 (1.4)	*	1	0	0	0	0					

Note. Number of injuries & (%): frequency of total injuries; I: incidence per 1000 player-hours; 95% CI = 95% Confidence Intervals.
Severity scores are the number of injuries in each category (0, 1-7, 8-28 or >28 days lost).
* Number too small to calculate incidence. Incidence rates and associated 95% confidence intervals were only calculated and reported for categories with ≥5 injuries. Lower limb severity data missing: match n=3, training n=1

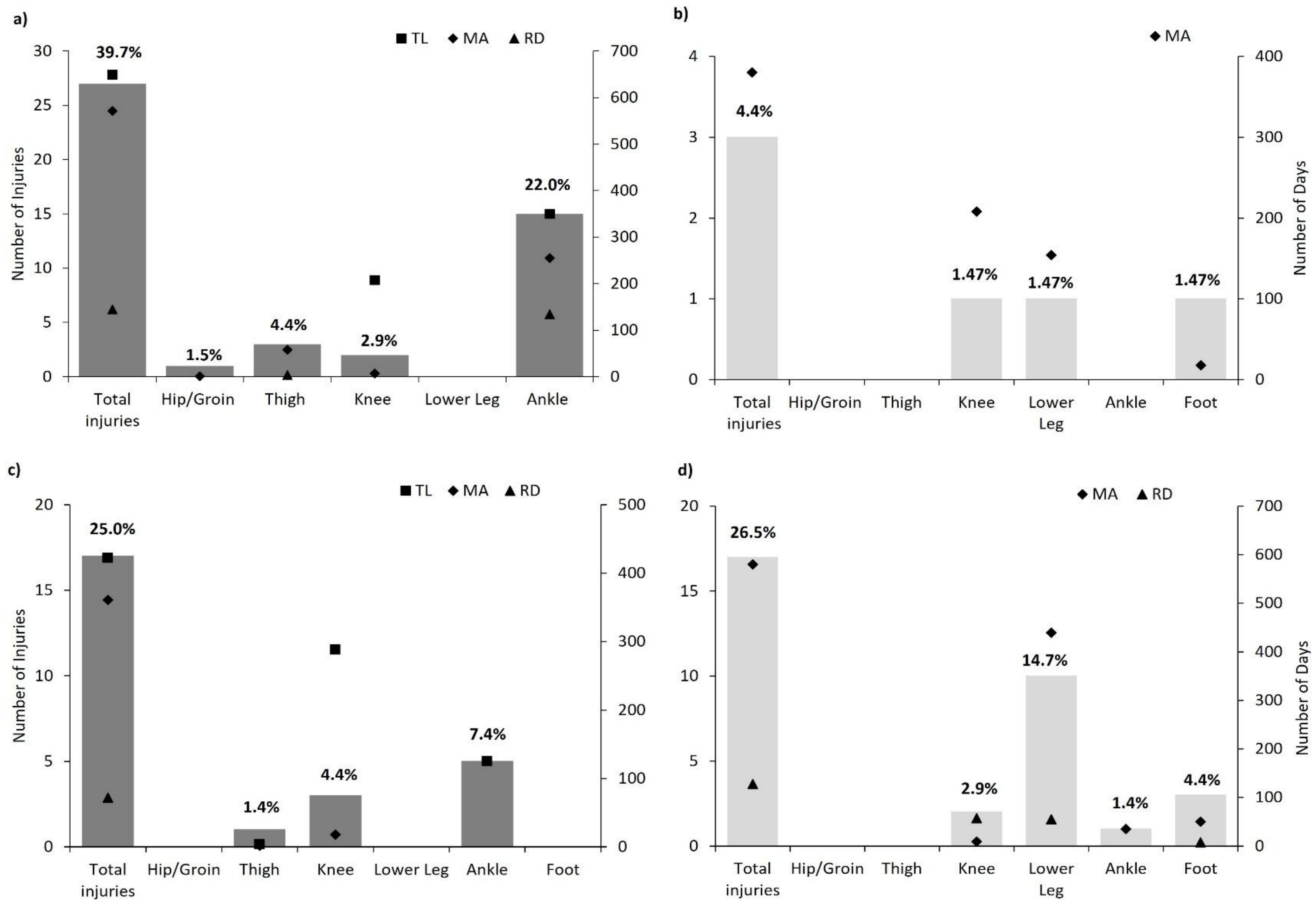

Figure 4.1 *Number of lower limb match (a, b) and training (c, d) injuries by injury mode (acute: a & c, overuse: b & d) and impact, compared with total injuries in each category*

Note. Percentage values represent the frequency of total injuries, excluding missing data. Injury impact values are total time-loss days (TL), medical attention days (MA) and restricted days (RD). Two recurrent match injuries were excluded from the figure.

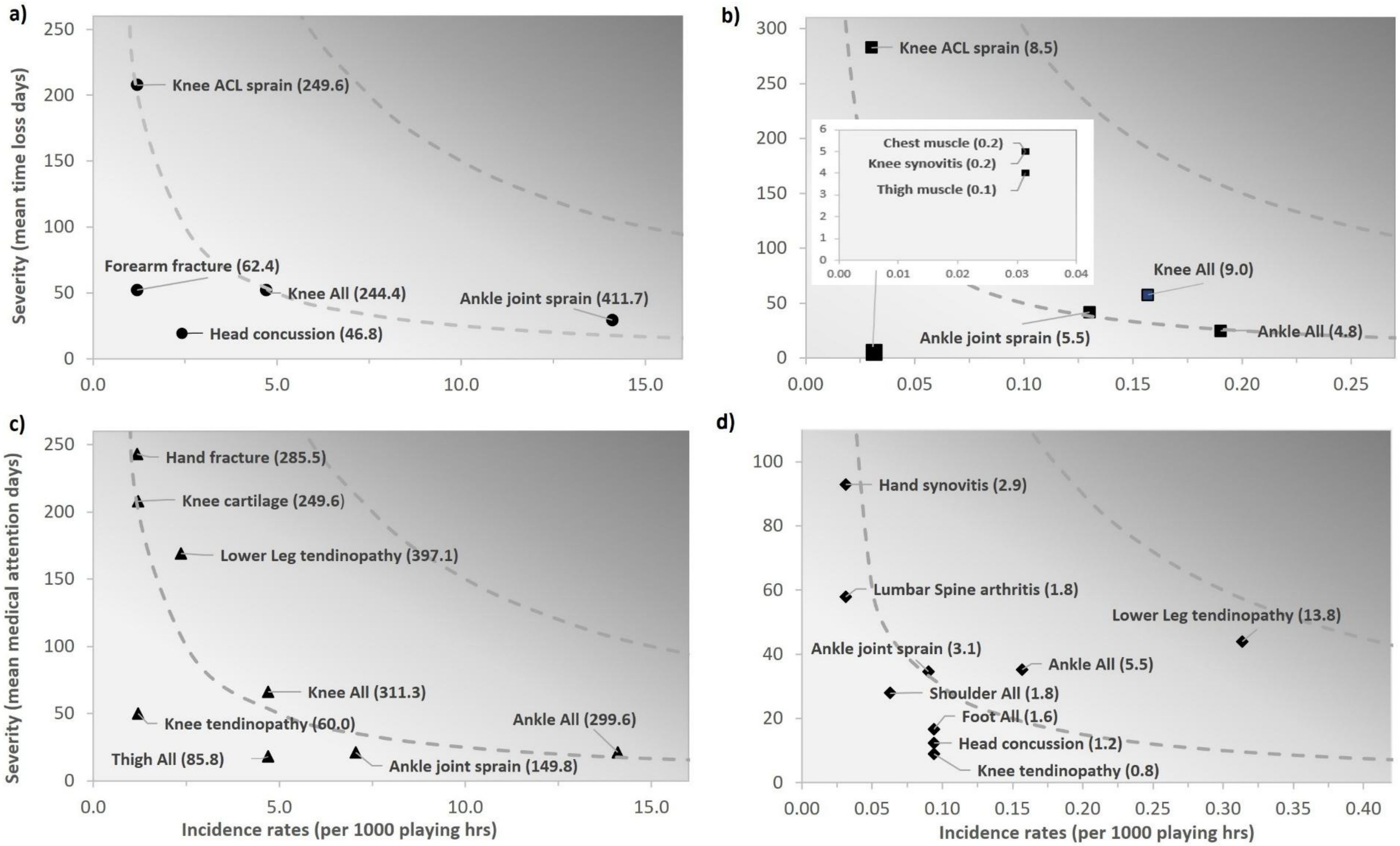

Figure 4.2 *Risk matrix of body area and pathology type burden*

Note. Severity is based on the TL days for a) matches and b) training and MA days for c) matches and d) training. The darker the grey, the greater the burden. The dotted grey lines represent points of equal burden. All injuries contributing to burden were included irrespective of injury frequency, as burden reflects both injury frequency and severity.

diagnosis. The highest TL burden in matches resulted from ankle joint sprains (411.7 days lost/1000 hours) and ACL sprains (249.6), while knee injuries posed the highest TL burden in training (9.0) (Figure 4.2a & 4.2b). Lower leg tendinopathy caused the highest MA burden in training (13.8) and matches (397.1) (Figure 4.2 c & d).

4.3.3.3 Injury by playing position and competition structure. Table 4.3 shows that the centre position (C) sustained the highest proportion of injuries in matches (n = 15; 21.4%) and training (n = 14; 20%), resulting in considerable impact in matches (TL: 522 days, RD: 112 and MA: 507) and MA in training (518 days). Ankle (matches: n = 6; training: n = 3), lower leg (match; n = 1; training: n = 5) and head injuries (match: n = 2; training: n = 2) were most prevalent in C, while WD experienced the most knee injuries (matches: n = 3; training: n = 2).

Nineteen injuries (27.1%) occurred in pre-season (63% in the final 2 months), while 51 (72.9%) occurred during the competition. In-season match injuries peaked during Block 2, in rounds 5–6 and 9 (n = 5; 7%), coinciding with the busiest match period (35 games in 7 rounds) (Figure 4.3a). Training injuries decreased post pre-season but also increased following double-header weekends in rounds 5–6 and 10–11 and the end of Block 3 (Figure 4.3b).

4.4 Discussion

This study supported the implementation of a systematic injury surveillance system in the VNSL and represents the first prospective assessment of injuries in elite UK netball over a whole preparation and competition season. It also provides the first comprehensive evaluation of match and training injuries in netball. Furthermore, it is one of the few netball studies to report data quality and introduces a novel approach for reporting non-time loss injury burden. The principal findings were that match injury incidence was nearly 40 times higher than training incidence. Most injuries occurred in the lower limb, and there were differences in the injury type, mode of onset, mechanism of onset, impact, and burden between matches and training.

4.4.1 Data quality

Injury recording using the PDMS had a high response rate and data completeness ≥98%, indicating that the system was feasible and acceptable for use within the elite VNSL environment. Training exposure calculations, although based on average team exposures rather than individual player data, were internally consistent, as reflected by low between-team variability (12% CV). However, considerable between-team variability in injury incidence rates was observed for both matches (81% CV) and training (94% CV). This difference, despite high data completeness, suggests variability in the interpretation and

Table 4.3 *Frequency and impact of match and training injuries by playing position*.

Playing Position	Match Injuries					Training Injuries				
	No. of injuries (%)	**I (95% CI)**	**TL**	**RD**	**MA**	**No. of injuries (%)**	**I (95% CI)**	**TL**	**RD**	**MA**
GS	3 (4.3)	*	52	0	3	2 (2.9)	*	0	13	156
GA	2 (2.9)	*	5	7	146	1 (1.4)	*	0	57	0
WA	1 (1.4)	*	0	0	15	1 (1.4)	*	0	8	0
C	15 (21.4)	17.62 (10.26–29.59)	522	112	507	14 (20.0)	0.44 (0.25–0.76)	4	17	518
WD	8 (11.4)	9.40 (4.38–19.21)	1	14	492	8 (11.4)	0.25 (0.12–0.51)	10	13	127
GD	5 (7.1)	5.87 (2.16–14.48)	69	12	84	6 (8.6)	0.19 (0.08–0.43)	283	32	68
GK	1 (1.4)	*	0	0	0	3 (4.3)	*	125	60	72

Note. Number of injuries & (%) frequency of total injuries. I: incidence per 1000 player-hours. 95% CI = 95% Confidence Intervals. GS = Goal Shooter; GA = Goal Attack; WA = Wing Attack; C = Centre; WD =Wing Defence; GD = Goal Defence; GK = Goal Keeper

* Number too small. Incidence and 95%CI were only reported for values n ≥ 5.

Injury Impact values are total time-loss days (TL), restricted days (RD) and medical attention (MA) days.

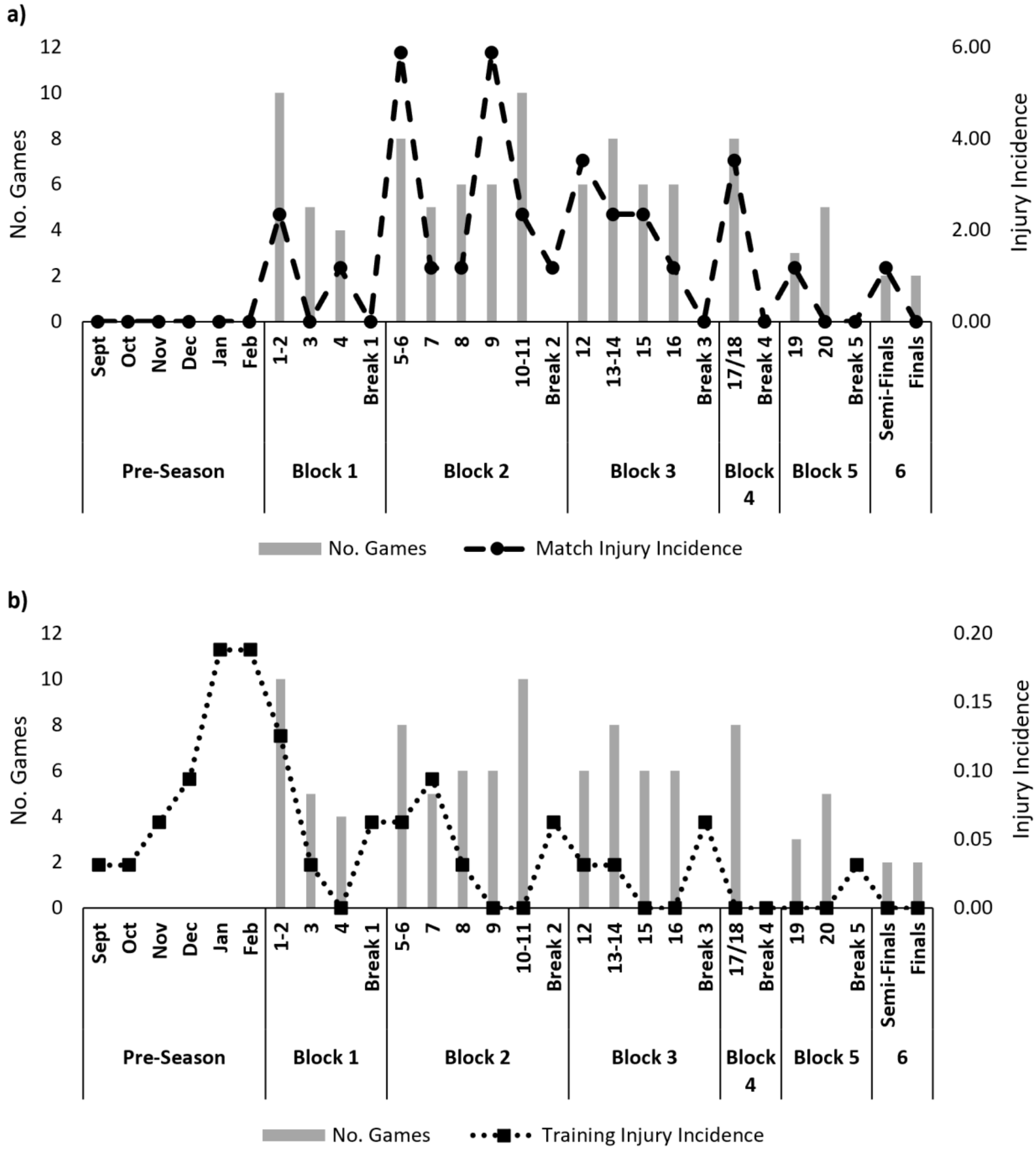

Figure 4.3 *Incidence of match (a) and training (b) injuries in relation to competition structure: pre-season training, number of games each round and across each block of games.*

Note. Block 1 = 12 February–1 March, Break 1 =10 days; Block 2 = 12 March–12 April, Break 2 = 12 days, Block 3 = 25 April–17 May, Break 3 = 10 days, Block 4 = 28–31 May, Break 4 = 12 days, Block 5 13–21 June, Block 6 (6) 26–27 June.

application of injury definitions and reporting thresholds across teams, and potential under-reporting in some settings (Edouard et al., 2016). Similar patterns of inter-team variability have been reported in other prospective injury surveillance systems, even where standardised definitions and centralised platforms were used (Bjørneboe et al., 2011; Engebretsen et al., 2012). A contributing factor may be the limited time available for part-time team physiotherapists to complete injury documentation alongside their additional clinical responsibilities, particularly during congested competition periods. These findings highlight that high-quality surveillance depends not only on system design but also on consistent user training and engagement. Ongoing education, clarification of injury definitions, and regular PDMS training are therefore recommended to improve consistency and further enhance data quality in future surveillance cycles.

4.4.2 Match and training injuries in the VNSL 2021 competition

Match injury incidence in this study (41.12/1000 hours) was considerably higher than training (1.10/1000 hours), consistent with trends in elite women's team sports, where match injuries exceed training by 6 to 13 times (King et al., 2019b; López-Valenciano et al., 2021; Mayhew et al., 2021). The magnitude of the match-to-training ratio observed likely reflects both the inherently higher risk profile of match-play and the challenges of capturing the full spectrum of training-related conditions within routine surveillance systems.

When comparing injury incidence rates with those reported in other elite women's team sports, differences in injury definitions should be considered. The present study used a medical-attention injury definition, capturing both time-loss and non-time-loss injuries. Compared with elite women's domestic football, which reported time-loss injuries only, the present study demonstrated a higher match injury incidence (41.12 vs. 19.2–19.6/1000 hours) but a lower training injury incidence (1.10 vs. 3.0–3.5/1000 hours) (López-Valenciano et al., 2021; Mayhew et al., 2021). In contrast, the present match injury incidence fell within the range reported for elite women's football tournaments (39.0–70.0/1000 hours), which used a comparable medical-attention injury definition (Mayhew et al., 2021). Match injury incidence was also higher than that reported in professional basketball (24.9/1000 hours), which used a similar reportable injury definition (Deitch et al., 2006). Compared with the pooled estimates from women's rugby, training injury incidence was similar to rugby (1.5/1000 hours), while match injury incidence was higher than rugby-15s (19.6/1000 hours) but lower than rugby-7s (62.5/1000 hours), although these comparisons should be interpreted cautiously because the pooled estimates included studies using varying injury definitions (King et al., 2019b). Within netball, tournament studies have reported match injury incidences of 54.76 in elite and 89.4 in sub-elite players (Janse van Rensburg et al., 2021; Smyth et al., 2020), supporting the higher match injury rates observed in the present study and aligning with evidence that tournament injury incidence is typically greater than that observed during season-long surveillance (Langeveld et al., 2012). Collectively, these findings reinforce the elevated injury risk associated with match-play in elite netball.Unlike professional basketball research, which found no differences in injury characteristics between matches and training (Moreno-Pérez et al., 2021), our study revealed clear distinctions. Acute injuries were more common in matches (40%), often due to player contact (31%), aligning with the 2019 World Cup findings (Janse van Rensburg, 2021). Conversely, overuse injuries were more frequent in training (27%), typically from non-contact mechanisms of onset (15%), with a similar rate of acute injuries (25%). While the overall impact of match and training injuries was comparable (TL, RD, MA, ID), match injuries were more severe, leading to greater total TL (>28 days: 9%; 585 days). In contrast, training injuries had a higher median TL in the most severe cases (>28 days: 190 days). One possible explanation for the substantially higher match injury incidence is that routine training may not consistently expose players to the physical demands experienced during competition. Previous research has demonstrated differences between the physical demands of training and match-play in elite netball and highlighted the importance of preparing athletes for competition-specific demands (Thomas et al., 2017; Brooks et al., 2020b). However, this explanation alone is unlikely to fully account for the present findings. Injury risk is recognised as multifactorial, with workload representing only one component of injury causation (Windt & Gabbett, 2017). Match-play also exposes athletes to contextual factors that are difficult to replicate during routine training, including greater player contact, unpredictable opponent interactions, and competition-specific decision-making demands. This interpretation is supported by the current findings, in which match injuries were predominantly acute and contact-related, whereas training injuries were more frequently overuse and non-contact in nature, suggesting that the differing injury profiles reflect not only workload, but also the unique physical and contextual demands of competition.The type of injury and their subsequent impact and burden also differed between matches and training. While the lower limb was the most frequently injured body region in both matches (39%) and training (36%), acute lateral ligament ankle sprains, often from athlete contact (67%), led to the highest severity (TL: 350 days and TL injury burden (411 days lost/1000 hours) in matches. In contrast, overuse tendinopathies, typically at the Achilles tendon (30%), resulting in no TL but high MA (439 days) and MA injury burden (14 days/1000 hours), were most common in training. As previously reported [13, 20], knee injuries were less frequent, but included two notable acute, non-contact ACL cases (match: 1; training: 1), causing considerable severity (match: 208 days; training: 288) and TL burden (match: 244; training: 9 days/1000 hours).

The match injury findings align with previous netball research, which has consistently identified ankle and knee injuries as the most frequent and severe (Botha et al., 2020; Finch et al., 2002; Hopper et al., 1995a; Hume & Steele, 2000; Janse van Rensburg et al., 2021; Langeveld et al., 2012; McManus et al., 2006; Pillay & Frantz, 2012; Sinclair et al., 2020; Singh et al., 2013; Smyth et al., 2020; Toohey et al., 2022). These injuries impact player performance and team success (Williams et al., 2016). Hence, we support Toohey et al.'s (2022) recommendation that prioritising acute lower limb injury reduction may be netball's most effective strategy for overall injury control. Additionally, our training injury data highlight a need to concurrently address overuse lower leg injuries due to the high medical attention burden they place on physiotherapists. Moreover, the effect of playing while undergoing treatment for overuse injuries is not well understood. Evidence suggests that non-time-loss injuries may precede time-loss injuries (Whalan et al., 2020; Stares et al., 2019), emphasising the need to explore how playing with overuse injuries influences the risk of subsequent injuries in netball to guide return-to-play strategies.

This study also noted increased player-contact concussion injuries (match: n = 2, training: n = 4). While concussion data in netball is limited (Horne et al., 2024; Downs et al., 2021), recent research identified them as the second most common injury in sub-elite netball (Smyth et al., 2020), warranting further investigation into a potential trend. The high overall rate of contact injuries (64%) suggests the increasing physicality of the elite game (Whitehead et al., 2021) is a concern for injuries. In-season injuries (73%) were notably higher than pre-season injuries (27%), contrasting with the 49% pre-season rate reported in Australia’s SSN (Toohey et al., 2022). While minimising injuries across all phases of competition is important, increasing rates reported during dense match periods requires a particular prevention focus. These findings highlight the need to enhance player resilience through appropriate conditioning programmes and effectively monitor and manage player workloads throughout the season. While training should aim to prepare players for the physical demands of competition, injury prevention strategies should also address the technical, tactical and contact situations unique to match-play, which may not be fully replicated during routine training. A greater understanding of the activities leading to injuries, particularly the circumstances leading to contact injuries, is therefore important for developing effective training programmes.To date, injury findings across playing positions have been inconsistent. In this study, the C position sustained the highest injury rates (matches: 21%, training: 20%), and TL (matches: 507 days, training: 69 days), consistent with the 2019 Netball World Cup findings (Janse van Rensburg et al., 2021) and reflective of the position's extensive court coverage (Davidson & Trewartha, 2008; Brooks et al., 2020) and versatile role. Conversely, we observed the highest overuse knee injuries (n = 4, 6%)

without TL in the WD position. Further research is needed to understand potential positional injury differences to aid in developing position-specific conditioning programs.

The findings of this study should, however, be interpreted in the context of the unique circumstances of the 2021 VNSL season. Data were collected during a single season affected by the COVID-19 pandemic, in which the competition format included reduced quarter durations, a condensed fixture schedule and periods of fixture congestion. These factors may have influenced player preparation, training exposure, workload distribution and injury risk. Consequently, although the overall injury profile and the substantially higher match injury incidence are consistent with findings reported in other elite team sports, the magnitude of the observed incidence rates and match-to-training injury relationship may not fully represent those of a typical VNSL season. Continued surveillance across multiple seasons is therefore required to establish whether these findings are representative of elite UK netball under normal competition conditions.

4.4.3 Research implications

Reducing netball injuries has clear benefits for player health, team performance, and the minimisation of financial and resource-related costs. This study highlights the importance of systematically reporting both match and training injuries to capture the full impact of injury across competitive settings, rather than focusing solely on match exposure. In particular, the inclusion of medical attention (MA) burden demonstrates the substantial strain that non–time-loss injuries place on medical and support staff, reinforcing the need for this metric to be incorporated in future surveillance studies. Accurate reporting of subsequent injuries, using established models such as that proposed by Hamilton et al. (2011), is essential to improve understanding of the relationship between non–time-loss and time-loss injuries. Continued and consistent data collection using the VNSL surveillance system will allow injury patterns to be monitored over time and provide a stronger evidence base to inform targeted injury prevention strategies in elite netball.

4.4.4 Strengths and limitations

The implementation of a centralised injury surveillance system across the VNSL represents a key strength of this study, providing the first prospective, season-long dataset describing both match and training injuries in elite UK netball. The system enabled the calculation of both time-loss and medical-attention injury burden, offering a more comprehensive assessment of injury impact than has previously been reported in netball. However, several limitations should be considered when interpreting the findings. First, the 2021 VNSL season was conducted under modified competition conditions due to COVID-19 restrictions, including a condensed fixture schedule, reduced quarter durations, and periods of fixture congestion. These contextual factors may have influenced injury incidence, injury burden and the observed relationship between match and training injuries, limiting direct comparison with injury data from typical VNSL seasons. Comparative data from uninterrupted seasons are therefore required to confirm whether the observed injury patterns are representative of elite UK netball under normal competition conditions.

Although overall response rates and data completeness were high, injury incidence rates showed substantial variability between teams, suggesting differences in interpretation or application of injury definitions and potential under-reporting. This variability limits the precision of team-level comparisons and highlights the importance of ongoing education and standardisation in surveillance practice. Training exposure estimates were derived from average team-level data rather than individual player records. While these estimates were internally consistent across teams, the use of aggregated exposure data limits the ability to link injuries to individual workloads or specific training activities. Future studies incorporating individual workload monitoring may improve exposure accuracy and support more detailed analyses of injury risk. Finally, injury mechanism of onset variables were limited to broad surveillance classifications, consistent with IOC recommendations. As such, this study was not designed to examine injury-inciting events or detailed biomechanical mechanisms. Combining surveillance data with systematic video analysis and input from players and medical staff represents an important next step for advancing understanding of how injuries occur in elite netball and is addressed in Chapters 5 and 6.

4.5 Conclusions

The implementation of a systematic injury surveillance system in the Vitality Netball Superleague provided the first prospective assessment of injuries in elite UK netball across a full preparation and competition season. The findings revealed match injuries were approximately 40 times more frequent than training injuries, confirming matches as the primary context of injury risk in elite UK netball. Acute, contact-related ankle and knee injuries were most prevalent during matches and imposed a substantial time-loss burden. In contrast, non-contact, overuse lower-leg injuries predominated in training and contributed a high medical attention burden despite minimal time-loss.

These findings highlight the need for prevention strategies that are specific to exposure context, with a primary focus on reducing acute lower-limb injuries in matches alongside improved management of overuse conditions during training. Further research is required to examine the impact of overuse injuries on subsequent injury risk and to better understand positional differences in injury patterns within elite netball.

Chapter 5: Development of a Standardised System to Identify Injury Inciting Events in netball: The Netball Injury Inciting Event Classification System (NIIECS)

This chapter addresses limitations in existing netball injury research identified in Chapters 2 and 3 by developing and evaluating the Netball Injury Inciting Event Classification System (NIIECS) for the systematic classification of injury-inciting events. Specifically, it reports the development and reliability of the situational and behavioural domains of the NIIECS, designed for application across match, training and non-inciting event contexts, with or without video footage. Biomechanical considerations are examined separately in Chapter 6.

5.1 Introduction

Injuries present a major barrier to performance and participation in women's team sports, but prevention efforts remain constrained by limited understanding of injury aetiology and causation (Crossley et al., 2020; Downs et al., 2021; Horne et al., 2024). Aetiology encompasses the complex interaction of intrinsic and extrinsic risk factors that influence susceptibility to injury. Injury causation is operationalised through the inciting event, which represents the final step that directly results in tissue damage (Meeuwisse, 1994). Hence, a comprehensive assessment of the inciting event, including the sequence of situational, behavioural, and biomechanical factors, is essential for understanding how injuries occur and for designing targeted interventions (Bahr & Krosshaug, 2005). However, research across many sports remains methodologically limited, with variation in definitions, terminology, and approaches hindering standardisation and comparability, thereby constraining the translation of findings into effective prevention strategies (Horne et al., 2024; Krosshaug et al., 2005; Mackay et al., 2023).

Netball is one of the leading global sports for women, yet it exhibits a high incidence of injury, particularly to the lower limb (Downs et al., 2021; Horne et al., 2025; Janse van Rensburg et al., 2022; Toohey et al., 2022; Whitehead et al., 2021). To date, injury causes have largely been evaluated using simplistic and inconsistent classifications in surveillance studies, with most research focusing on match injuries and limited analysis of training-related inciting events and overuse conditions (Downs et al., 2021; Horne et al., 2024). Some studies classify injuries solely by mode of onset or contact type, while others use more detailed but disparate systems and definitions (Downs et al., 2021; Horne et al., 2024; Whitehead et al., 2021). These inconsistencies hinder cross-study comparability and limit the application of findings to evidence-based injury prevention (Horne et al., 2024; Whitehead et al., 2021). Despite these limitations, existing studies have yielded valuable insights, consistently identifying landing from a jump as the predominant movement pattern associated with lower-limb injuries, particularly those involving the ankle and knee. Slips, trips, and player collisions have also reported as frequent contributing circumstances (Hopper et al.1995; Hopper & Elliott, 1993; Joseph et al., 2019; Langeveld et al., 2012; Pillay & Frantz, 2012). However, these findings offer limited contextual information about the situational and behavioural factors surrounding injury events, including the phase of play, player actions, and opponent interactions. As a result, current evidence provides only a partial understanding of how and why injuries occur within the complex and dynamic environment of netball.

Video-based analysis has increasingly been used to investigate injury-inciting events in sport (Hendricks et al., 2020). However, only three studies in netball have adopted this approach, focusing on ACL injuries (Belcher et al., 2022; Stuelcken et al., 2016) and lateral ankle sprains (Stuelcken et al., 2024), with the most recent study published after completion of Chapter 2 and the scoping review reported in Chapter 3. Although these studies provide detailed situational and biomechanical insights, their scope is narrow and does not reflect the wider range of injuries occurring across the sport. Moreover, they were conducted without a standardised framework for evaluating inciting events (Horne et al., 2024) limiting consistency and comparability. The recent consensus framework defining standardised video-based performance descriptors for netball (Mackay et al., 2023) represents an important methodological advance, but further adaptation is required to create a sport-specific system capable of systematically characterising injury-inciting events. This need is underscored by the fact that most existing analyses focus solely on match-play, despite many injuries occurring in training or developing gradually without a clear inciting event (Downs et al., 2021; Horne et al., 2024), contexts that are rarely captured on video. These challenges highlight the need for a unified framework that can document injury events across match, training and overuse contexts, using either video or structured self-report data. This dual-mode capability is especially important as video footage captures only around half of reported injuries (Andersen et al., 2004: Arnason et al., 2004; Krosshaug et al., 2007b). As Krosshaug et al. (2005) proposed, combining video-based and athlete-derived information may offer the most practical and comprehensive approach to understanding inciting events.

Therefore, the primary aim of this study was to develop the first netball-specific classification system for describing the situational and behavioural characteristics of injuries across match, training, and injuries without an identifiable inciting event. A key requirement was that the system could be applied with or without video footage, enabling use in video-based and non-video (athlete- or clinician-reported) contexts. A secondary aim was to evaluate the inter- and intra-rater reliability of the classification system and assess its practical feasibility and usability in applied settings, including coding time and ease of application when using match video clips. This study focused on the situational and behavioural domains of the injury event. A biomechanical domain within the classification framework was piloted separately to explore the conceptual and practical feasibility of incorporating biomechanical factors and is addressed in Chapter 6.

5.2 Methods

This study comprised two sequential phases: (a) development and validation of the Netball Injury-Inciting Event Classification System (NIIECS) through a modified Delphi process; and (b) pilot testing to evaluate its inter- and intra-rater reliability, practical feasibility, and usability in applied settings. Ethical approval was granted by Brunel University's College of Health, Medicine and Life Sciences Research Ethics Committee (Ref: 12619-A-May/2025- 54209-2). Written informed consent was obtained from expert participants. Documentation relating to ethical approval and expert participant consent materials is provided in Appendix C (C1–C2). Permission from England Netball for use of 2021 Vitality Netball Superleague match footage, together with team gatekeeper and player consent, was obtained under the ethics approval for Study 2 and is therefore provided in Appendix B.

5.2.1 Development of the NIIECS

The development of the NIIECS followed a two-phase process aligned with established sport video-analysis consensus methods (Hendricks et al., 2020; Mackay et al., 2023). Phase 1 involved constructing an initial draft framework developed through a systematic literature review and existing netball consensus descriptors, with additional variables incorporated to capture training and overuse injury circumstances. Phase 2 employed a modified Delphi method, guided by the Conducting and REporting DElphi Studies (CREDES) guidelines (Jünger et al., 2017) and methodological recommendations for good Delphi practice (Diamond et al., 2014), to achieve structured expert consensus and establish content validity. The Delphi approach was intentionally adapted because many situational and behavioural descriptors had already undergone consensus development within the netball video-analysis framework (Mackay et al., 2023). Prior to the Delphi rounds, an England Netball medical focus group reviewed the draft framework to confirm its clinical relevance, appropriateness of terminology and clarity of response options. This preliminary review served the preparatory role normally fulfilled by a pre-Delphi pilot and therefore a separate pilot stage was not undertaken. The Delphi phase then focused on validating and refining the framework to ensure its applicability across match and training contexts, and both video-based and non-video (athlete- or clinician-reported) injury settings.

5.2.1.1 Phase 1: Draft Development. The initial draft of the Netball Injury Inciting Event Classification System (NIIECS) was developed by the author drawing on domain expertise in netball playing, coaching, and performance analysis, alongside biomechanics and sports injury research. The conceptual structure of the framework was informed by the model proposed by Bahr and Krosshaug (2005), which distinguishes three domains of injury-inciting events: playing situation, player and opponent behaviour, and biomechanical factors. The present study focused on the situational and behavioural domains, with the biomechanical domain addressed separately. The initial draft framework was developed using evidence identified through a systematic search of the literature employing video or observational methods to analyse injury-inciting events across netball and other sports. Articles published up to 20 May 2025 were identified through searches of SPORTDiscus, MEDLINE, CINAHL, Academic Search Complete (EBSCOhost), PubMed, Scopus and Web of Science. The search strategy combined the following terms across all databases: (sport* OR netball OR athlete* OR football OR soccer OR rugby OR cricket OR tennis OR basketball OR racing OR handball OR Volleyball OR skiing) AND (Injur* AND (mechanism* OR "inciting event*" OR cause* OR situation* OR circumstance*)) AND ("Video analysis" OR video-based OR “observational analysis”). Eligible studies were peer-reviewed, English-language research that analysed injury-inciting events in any sport. After merging datasets, duplicates were removed and titles and abstracts were screened by the author, with a second researcher independently reviewing a subset to support methodological rigour. Full-text screening was subsequently undertaken, and any discrepancies were resolved through discussion.

Evidence from the included studies was synthesised to identify the key situational and behavioural concepts used to characterise injury-inciting events across sports. Descriptors and coding categories considered both relevant and feasible for application in the netball context were developed from these concepts and combined with general injury information (e.g., injury date, competition name and standard, body region and player position) to construct the initial draft NIIECS framework. This preliminary framework was subsequently reviewed by an England Netball medical focus group to assess its clinical relevance, clarity and practical applicability within the elite netball context. The group recommended aligning terminology with the netball video-analysis consensus framework of Mackay et al. (2023) to ensure sport-specific consistency. They also advised refining terminology, incorporating broader response options ("Other", "Unknown"), and clarifying operational definitions to improve consistency and reduce ambiguity. Following feedback from the England Netball medical focus group, the draft framework was refined and organised into four main sections: (i) general information (12 categories), (ii) injuries without an inciting event (2 categories), (iii) training injuries (9 categories), and (iv) match injuries (26 categories), with the latter subdivided into playing situation and player/opponent behaviour. Finally, the framework was formatted for dual-mode use through a Microsoft Excel spreadsheet for descriptive data entry and a Dartfish tagging panel (Dartfish Pro S, v10.21; Dartfish Ltd., Fribourg, Switzerland) for video-based analysis. Detailed user instructions and variable definitions were developed to support consistent coding. This refined draft formed the basis for the expert consensus process undertaken in Phase 2 (see C3, Appendix C).

5.2.1.2 Phase 2: Modified Delphi Process. Phase 2 established the NIIECS consensus group, purposively sampled to represent key domains of expertise, including clinical sports medicine, netball performance, and sports science research. Eligibility required a minimum of five years' experience in at least one domain and evidence of expertise through peer-reviewed publication or professional practice. The group consisted of fifteen experts (n = 8 women, n = 7 men) from a range of countries and cultural backgrounds (England: n = 10; Greece/Cyprus: n = 4; Saudi Arabia: n = 1). Primary expertise included netball performance (n = 2; coach = 1, performance analyst = 1), clinical sports medicine (n = 7; netball practitioners = 3, other sports = 4), and sports science research (n = 6). Several participants possessed multidisciplinary expertise (e.g., physiotherapist and sports injury researcher; or performance analyst, coach, and injury researcher) and prior experience as netball players. The mean number of years' professional experience across domains was 30 (range = 5–38 years). The panel comprised clinicians and researchers with experience across multiple sports, including basketball, cricket, football, and rugby, alongside netball practitioners, ensuring representation of expertise in comparable injury documentation systems. Practitioners represented elite, sub-elite, and educational (school and university) levels, while researchers ranged from early career to professorial positions. The breadth of expertise domains represented within the NIIECS consensus group is presented in Figure 5.1.

A two-round Delphi consensus process was used to refine the NIIECS variables and categories, intentionally limited to balance methodological rigour with the practical constraints of expert availability, consistent with approaches used in recent sport-specific consensus frameworks (Hendricks et al., 2020; Mackay et al., 2023). Experts were provided with both formats of the NIIECS (Microsoft Excel spreadsheet and Dartfish tagging panel) for reference and received introductory information outlining the framework and review procedures. An online survey was then distributed, in which each expert independently rated their agreement with every variable and category using a five-point Likert scale (1 = strongly disagree to 5 = strongly agree) and provided qualitative feedback on structure, content and

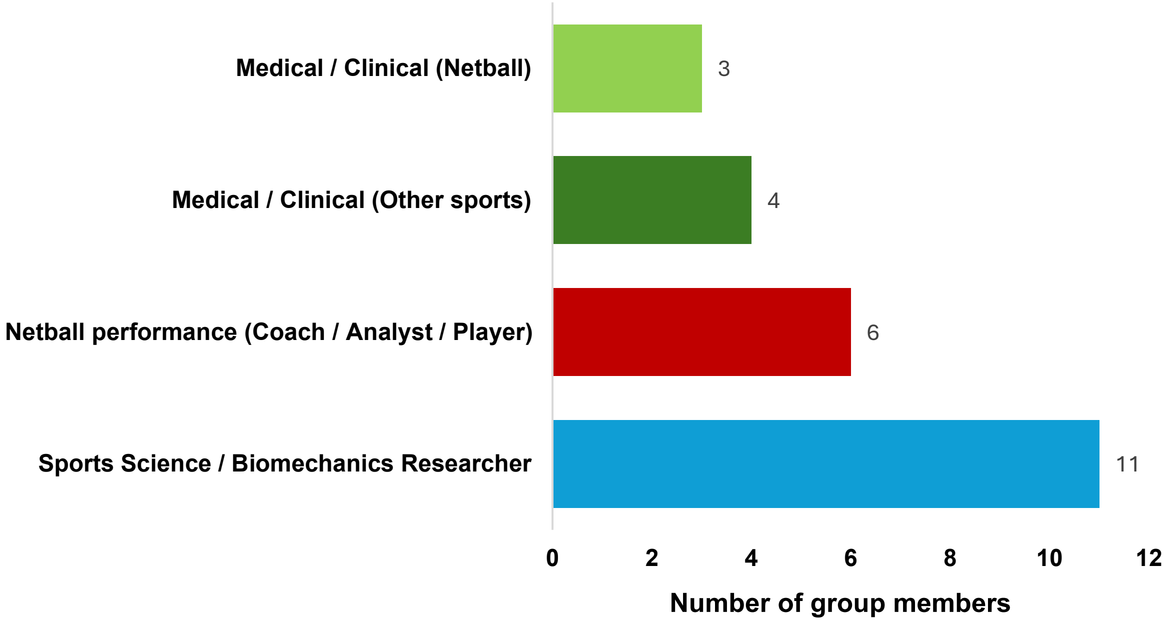

Figure 5.1 *Expertise Domains Represented within the NIIECS Consensus Group*

Note. Counts reflect expertise domain membership and exceed n = 15 because some experts contribute to multiple domains.

definitions, guided by five open-ended questions (C3, Appendix C). The process incorporated structured, anonymous feedback to support iterative refinement while maintaining transparency, minimising bias and ensuring equal contribution from all participants. Round 1 remained open for four months, with consensus defined a priori as ≥80% of experts rating an item as “strongly agree.” Items that did not reach this threshold were revised using the qualitative feedback provided and redistributed in Round 2, accompanied by anonymised summary ratings and a brief explanation of the changes to support informed reconsideration. In Round 2, consensus was defined as ≥80% of experts selecting either “agree” or “strongly agree”. Agreement levels were summarised as median (IQR). All revisions and their rationale were documented across both rounds (Table C1, Appendix C), and minor non-substantive adjustments made after the final round are reported in the Results (Section 5.3).

5.2.2 Pilot testing, reliability and practical usability of the NIIECS

Following expert consensus, the NIIECS underwent pilot testing to evaluate its real-world feasibility, inter- and intra-rater reliability, and practical usability. Real-world feasibility was assessed by examining whether the framework could be applied to real match-play injury events under typical performance-analysis conditions, using the operational definitions established through the Delphi process. Inter- and intra-rater reliability were evaluated by quantifying agreement between and within raters when classifying the same injury events.

Practical usability was assessed through analysis of coding time, providing an indication of the efficiency and burden of applying the system in applied settings. Together, these evaluations align with recommended post-development assessment practices for sport-specific video-analysis frameworks (Hoenig et al., 2024; Hopkinson et al., 2022).

Reliability of the NIIECS was assessed using injury video clips from the 2021 Vitality Netball Superleague (VNSL) season. Video footage (10–20 seconds per injury) was supplied by team performance analysts and consisted of a single end-court camera view, reflecting the typical constraints of applied netball analysis. Of the 35 match injuries recorded in 2021, 18 (51%) had accompanying video. Nine ankle-injury events with adequate video clarity were selected to minimise variability in injury-inciting event characteristics. Only variables requiring visual judgement were coded; predetermined surveillance-derived fields (e.g., competition details, injury environment, injury body area) were completed but excluded from the reliability assessment. This approach enabled a focused evaluation of the video-based components of the system. Reliability analysis was completed by three reviewers with complementary expertise in netball performance analysis, applied sports science research, and clinical sports medicine. All reviewers received structured training on use of the NIIECS and Dartfish tagging interface. Before coding, reviewers agreed on the index frame (moment of injury) to ensure a consistent temporal reference. Each reviewer then independently coded all nine clips, with clip order individually randomised to minimise order effects. For intra-rater reliability, one reviewer re-coded all clips after an 8–day interval using a newly randomised sequence. This timeframe was chosen to reduce recall bias and broadly reflect the interval between competitive fixtures in league netball structures. All footage and associated data were fully anonymised in accordance with institutional ethical procedures.

Inter- and intra-rater reliability were quantified using percentage agreement and Gwet's AC1 coefficient (Gwet, 2014), calculated in R (version 4.5.0; R Core Team, Vienna, Austria) using the *irrCAC* package. Gwet's AC1 was selected because the NIIECS comprises nominal variables with imbalanced category frequencies, conditions under which Cohen's kappa is known to yield unstable or biased estimates (Feinstein & Cicchetti, 1990). AC1 provides more robust and stable agreement coefficients for categorical systems dominated by low-prevalence response options (Gwet, 2014; Wongpakaran et al., 2013). Gwet's AC1 coefficient is defined as:

$$AC1 = (Pa - Pe) / (1 - Pe)$$

where P_a represents the observed proportion of agreement between raters, and P_e represents the chance-expected agreement estimated using Gwet's method, which adjusts for category prevalence and marginal probability imbalance (Gwet, 2014). This adjustment reduces the paradoxical behaviour observed with Cohen's kappa when category prevalence is highly skewed. Reliability was interpreted using the magnitude of AC1 values and their associated 95% confidence intervals, with agreement levels descriptively contextualised using commonly applied interpretive benchmarks (Landis & Koch, 1977). Coding time was measured as the duration (min:s) required to complete full coding of each injury clip using the NIIECS. Reviewers recorded coding duration for each clip during both the inter-rater and intra-rater assessments and mean ± SD coding times were calculated for each reviewer (Hoenig et al., 2024).

5.3 Results

5.3.1 Initial development of the NIIECS

The systematic literature search described in Section 5.2.1.1 yielded 189 studies examining injury-inciting events using video-based or structured observation methods (Figure 5.2). Evidence from these studies was mapped to identify relevant observational models, classification approaches and sport-specific descriptors for injury-event analysis. The resulting draft framework drew on key methodological domains, including foundational observational models (Andersen et al., 2003; Arnason et al., 2004; Krosshaug et al., 2007b; Olsen et al., 2004), studies refining sport-specific behavioural and situational descriptors (Della Villa et al., 2020; Serner et al., 2019; Waldén et al., 2015), consensus-based video analysis frameworks (Aiello, 2023; Hendricks et al., 2020; Lucas et al., 2022) and reliability-tested systems (Achenbach et al., 2021; Andersen et al., 2003; Hoenig et al., 2024; Hopkinson et al., 2022; Makdissi & Davis, 2016; Savage et al., 2011). Particular emphasis was placed on netball-specific studies (Belcher et al., 2022; Stuelcken et al., 2016, 2024), with consensus descriptors from Mackay et al. (2023) providing the sport-specific foundation for the situational and behavioural categories. Overall, 53% (n = 101) of included studies focusing on invasion sports contributed to the development of the NIIECS.

5.3.2 Expert consensus

Fifteen experts completed Round 1 of the Delphi process, and twelve participated in Round 2 (80% retention). In Round 1, 70% (n = 31) of items reached the predefined consensus threshold (≥80% "strongly agree"), with qualitative feedback primarily focused on improving clarity, reducing redundancy, and enhancing the practical usability of the framework. Based on this feedback, the framework was refined to better differentiate training from match injuries, ensuring the full spectrum of netball training activities (e.g., drills, conditioned play, intra- squad matches) was represented, while restricting the Match Injuries domain to competitive fixtures only. Instructions and definitions were also revised to improve

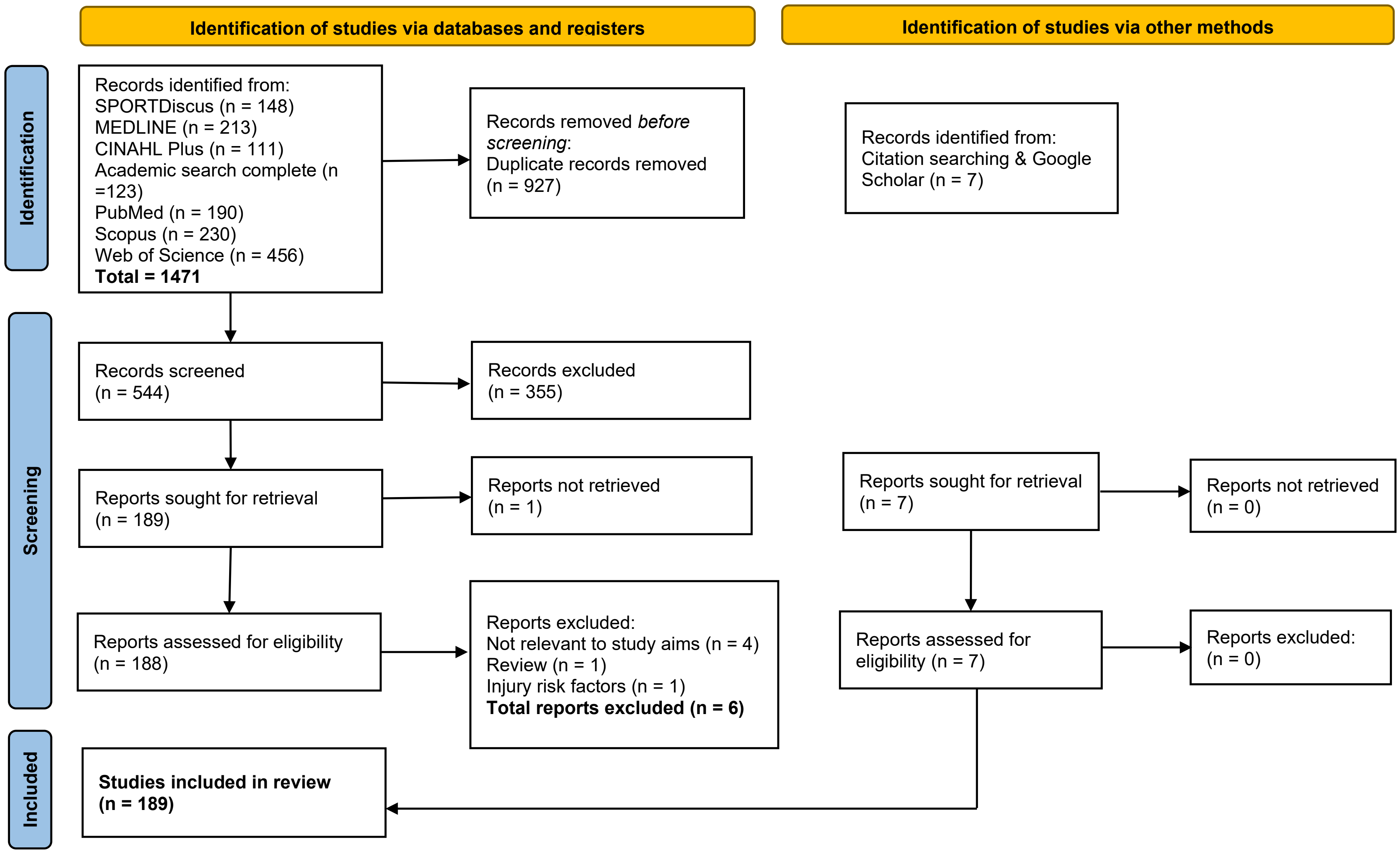

Figure 5.2 *Flowchart of selection process for eligible studies*

consistency, “Unknown/Unclear” and “Other (specify)” response options were added throughout, and several redundant or ambiguous variables were removed or consolidated. Minor adjustments were also made to specific categories that had achieved consensus in Round 1 where qualitative feedback indicated opportunities to improve clarity, precision, or usability.

In Round 2, the refined NIIECS draft was forwarded for further review. The categories that had not achieved consensus in Round 1 were re-rated, and experts were again invited to provide feedback on the framework updates. All categories subsequently reached the predefined consensus threshold (≥ 80 % “agree” or “strongly agree”), resulting in 100% agreement across all framework sections (Table 5.1). Median ratings across all variables were consistently high (5.0 [IQR 4–5] to 5.0 [IQR 5–5]), demonstrating strong expert agreement on the relevance, clarity, and completeness of the final framework. Following completion of the final round, minor usability and definitional edits were made to update the framework; these were considered non-substantive and therefore did not require an additional Delphi round. Category-level results, including, individual percentage agreement, median and interquartile range (IQR) values, and summary modifications made between rounds, are presented in Table C1, Appendix C.

5.3.3 Pilot testing, reliability and practical usability

Inter-rater reliability varied across NIIECS descriptors (Table 5.2). The highest agreement was observed for contextual and landing-related variables, which consistently showed percentage agreements ≥78% and AC1 values between 0.82 and 1.00 (almost perfect agreement). Within these domains, the highest-agreement descriptors included injured side, location on court, location in the goal circle, team playing phase, playing action at injury, and all landing-related items. Jumping variables and contact anticipation showed substantial agreement (AC1 = 0.65–0.75; percentage agreements ≥67%). Descriptors requiring greater interpretive judgement showed more variability. Player movement before injury, contact nature, and contact stance produced AC1 values around 0.43–0.46 (moderate agreement). Movement direction, change in movement speed, contact timing and type, and umpire decision demonstrated the lowest agreement (fair agreement; AC1 = 0.22–0.37; percentage agreement often <50%), reflecting the challenge of consistently identifying more nuanced or ambiguous features from match video. Confidence intervals for several descriptors were wide, as a result of the small number of available injury cases (n = 9), indicating greater uncertainty in agreement estimates for lower-performing items.

Intra-rater reliability was stronger overall (Table 5.2). Percentage agreement ranged from 78% to 100%, and AC1 values were predominantly high (almost perfect; typically ≥0.81)

Table 5.1 *Summary of consensus achievement and final median (IQR) ratings by NIIECS section*

Variable	No. of Categories	Categories Reaching Consensus in Round 1	Categories Rated in Round 2	Items Achieving Consensus	Final Median (IQR)
General Injury Information	15	8	7	100 %	5.0 (4–5)
Injuries with No Inciting Event	2	2	0	100 %	5.0 (4–5)
Training Injuries (Total)	27	17	10	100 %	5.0 (4–5)
Training Injury Information & Training Situation	7	5	2	100 %	5.0 (5–5)
Netball-specific Training Injury Information †	13*	9*	4	100 %	5.0 (4–5)
If Relevant: Playing Situation †	7*	3*	4	100 %	5.0 (5–5)
Match Injuries (Total)	25	15	10	100 %	5.0 (4–5)
Match Information and Playing Situation	10	6	4	100 %	5.0 (4–5)
Player/Opponent Behaviour	15	9	6	100 %	5.0 (4–5)

Note. IQR = interquartile range; NIIECS = Netball Injury Inciting Event Classification System. † New sections added to the Training Injuries domain after Round 1.

* Categories first rated under Match Injuries in Round 1 were included in the Training Injuries domain for Round 2; only those not achieving consensus were re-rated in Round 2

for spatial context, playing action at injury, jumping variables, and all landing-related descriptors. Contact-related descriptors (contact nature, stance, and anticipation) also demonstrated strong within-rater consistency, with AC1 values of 0.71–0.87 (substantial to almost perfect agreement). Moderate agreement was observed for descriptors requiring greater interpretive judgement, including player movement before injury, movement direction, change in movement speed, and contact timing and type (AC1 = 0.44–0.60). Overall, all descriptors demonstrated at least moderate within-rater stability, with no evidence of poor consistency. As in the inter-rater analysis, wider confidence intervals were observed for variables with lower agreement, likely due to the small number of injury events.

Practical usability analysis showed mean coding times of 7.35 ± 1.65 min for Reviewer 1, 8.22 ± 2.58 min for Reviewer 2, and 4.45 ± 0.54 min for Reviewer 3 during the inter-rater assessment, with an overall mean of 6.67 ± 2.21 min across reviewers. Coding times decreased in the intra-rater assessment, from 7.35 ± 1.56 min in Round 1 to 5.26 ± 0.77 min in Round 2, indicating reduced coding duration with repeated application of the framework.

5.3.4 Final NIIECS Framework

Following the pilot testing, several targeted refinements were made to enhance category clarity and support more consistent coding. Definitions were updated where inter-rater agreement indicated ambiguity, for example, clarifying that playing action at injury refers specifically to the action performed by the injured player. Categories with lower agreement were streamlined by reducing unnecessary granularity, particularly within the player movement before injury and movement direction variables, where distinctions such as running intensity and diagonal movements proved difficult to apply reliably. The speed-change descriptor was revised to apply only when the player was running (speed change [if running]), reflecting the contexts in which acceleration and deceleration can be meaningfully observed. No structural changes were made to the contact-related or umpire-decision categories, as lower reliability in these items appeared to reflect video quality constraints rather than conceptual limitations. These refinements informed Version 1.0 of the NIIECS, which is provided in Excel format via a restricted Zenodo link, and its overall structure is illustrated in Figure 5.3.

5.4 Discussion

This study developed and evaluated the first netball-specific framework designed to capture the situational, behavioural, contextual and environmental factors associated with injury events. Building on the sport-specific descriptors proposed by Mackay et al. (2023), the Netball Injury Inciting Event Classification System (NIIECS) operationalises and extends this work into a comprehensive injury-inciting event tool. It addresses key gaps identified in

Table 5.2 *Inter- and intra-rater agreement and reliability for NIIECS Variables (percentage agreement and Gwet's AC1 with 95% CI)*

Variable	Inter-Rater % Agreement	Inter-Rater AC1	Inter-Rater 95% CI	Intra-Rater % Agreement	Intra-Rater AC1	Intra-Rater 95% CI
Injured Side	100%	1.00	1.00–1.00	100%	1.00	1.00–1.00
Location on Court	78%	0.83	0.60–1.06	100%	1.00	1.00–1.00
Location in Goal Circle	78%	0.82	0.59–1.06	89%	0.86	0.58–1.14
Team Playing Phase	78%	0.82	0.59–1.06	89%	0.86	0.58–1.14
Player Movement Before Injury	33%	0.43	0.13–0.73	67%	0.60	0.21–1.00
Movement Direction	11%	0.27	0.05–0.48	67%	0.62	0.25–1.00
Change in Movement Speed	11%	0.22	0.01–0.43	67%	0.59	0.18–1.00
If Jumping: Type	67%	0.72	0.39–1.05	100%	1.00	1.00–1.00
If Jumping: Relative Elevation	67%	0.75	0.49–1.02	100%	1.00	1.00–1.00
If Landing: Type	89%	0.91	0.73–1.09	100%	1.00	1.00–1.00
If Landing: Balance	89%	0.87	0.60–1.14	89%	0.85	0.55–1.16
If Landing: Footwork Violation	100%	1.00	1.00–1.00	89%	0.85	0.54–1.16
Playing Action at Injury	67%	0.83	0.61–1.05	100%	1.00	1.00–1.00
If Contact: Timing and Type	33%	0.37	0.02–0.72	56%	0.44	0.00–0.91
If Contact: Nature	33%	0.46	0.16–0.76	78%	0.71	0.31–1.10
If Contact: Stance	33%	0.46	0.20–0.73	89%	0.84	0.52–1.16
If Contact: Anticipation	56%	0.65	0.34–0.95	89%	0.85	0.55–1.15
Umpire Decision	22%	0.30	0.01–0.59	67%	0.44	0.00–1.10

Note. NIIECS = Netball Injury Inciting Event Classification System; AC1 = Gwet's Agreement Coefficient; 95% CI = 95% confidence interval

Studies 1 and 2, including the absence of standardised injury-event documentation and the limited representation of training-related and gradual-onset injuries. The NIIECS is designed as a dual-mode system for use with or without video footage through an Excel-based classification workbook (with defined categories, dropdown response options and coding guidance) and a corresponding Dartfish tagging panel for video-based coding. It can be used to support standardised documentation of injury circumstances, providing practical utility for clinicians, performance analysts and researchers. Importantly, Version 1.0 is fully operationalised and ready for applied use, with pilot testing demonstrating acceptable reliability and feasible coding time for video-based match injury events. Further validation across training and non-video (athlete- or clinician-reported) settings will strengthen broader implementation.

The NIIECS was developed to address the methodological inconsistencies and absence of a standardised, netball-specific framework for classifying injury-inciting events across injury types (Belcher et al., 2022; Downs et al., 2021; Horne et al., 2024; Stuelcken et al., 2016, 2024). Development of the NIIECS followed a rigorous, evidence-informed and iterative process comprising a literature review, stakeholder input, a two-round Delphi process aligned with established consensus standards (Diamond et al., 2014; Junger et al., 2017) and sport-specific frameworks (Hendricks et al., 2020; Mackay et al., 2023). This was followed by pilot testing to evaluate practical feasibility and reliability. The Delphi process was intentionally adapted to refine and extend the netball-specific descriptor set proposed by Mackay et al. (2023). Several of these descriptors were incorporated directly into the initial NIIECS draft, alongside additional categories including those required to capture training injuries and injuries without a distinct inciting event. During the Delphi rounds, experts contributed multidisciplinary perspectives that strengthened the conceptual clarity and applicability of the framework. Although some clinicians raised concerns regarding the practicality of distinguishing certain highly granular categories, these items nonethelessreached consensus and were therefore retained at this stage, consistent with Delphi methodology. The resulting NIIECS comprises four sections (Figure 3), with data recorders completing the General Injury Information section followed by one of three sections: Injuries with No Inciting Event, Training Injuries or Match Injuries. Collectively, the framework captures the situational, behavioural, contextual and environmental features of injury events, providing a comprehensive foundation for consistent documentation across relevant settings.

While the Delphi process established the conceptual clarity of the NIIECS, the pilot study was essential for evaluating its performance in applied settings and ensuring an appropriate balance between scientific precision and practical usability. Overall, most visually judged

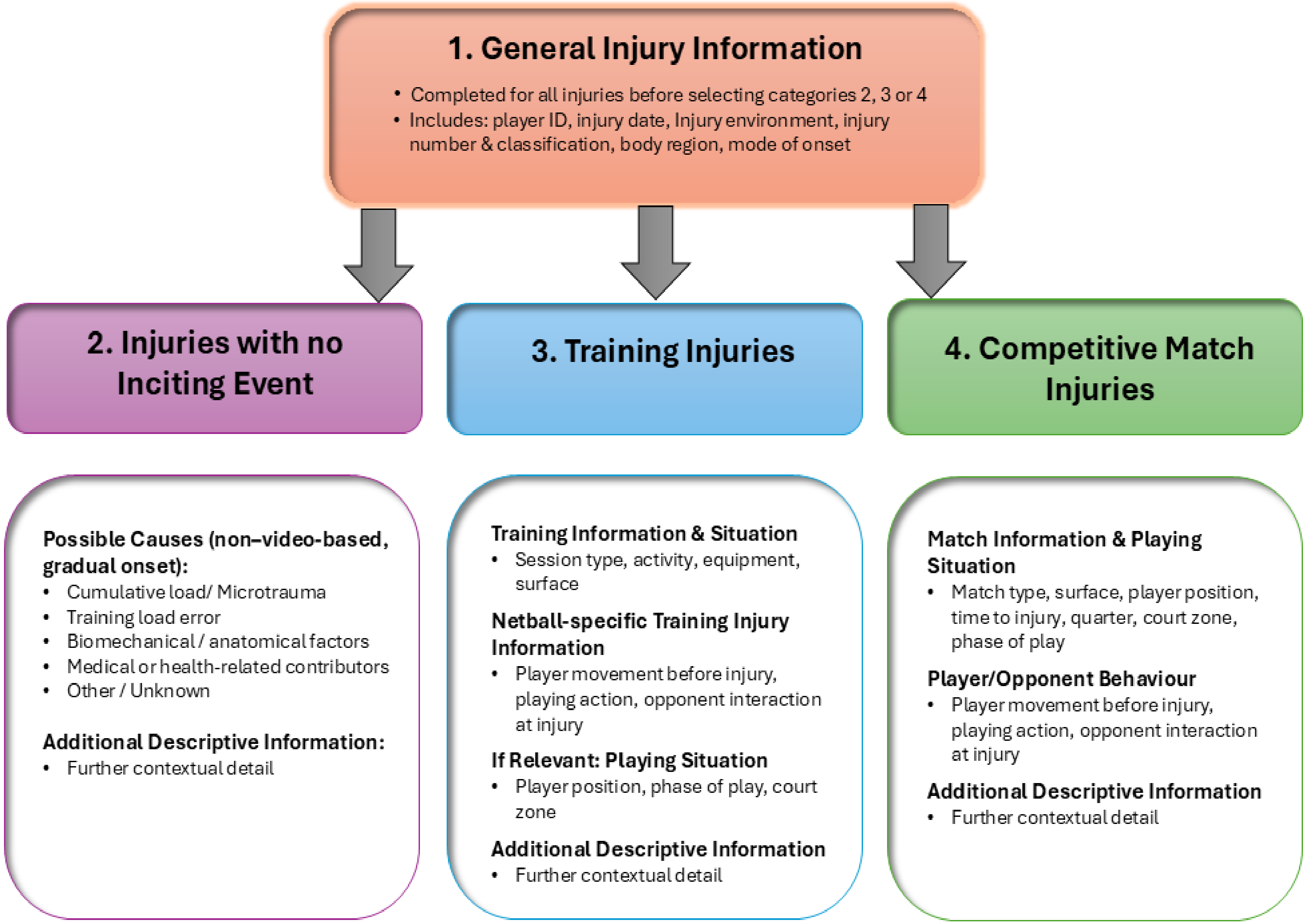

Figure 5.3 *Schematic of Netball Injury Inciting Event Classification System*

variables demonstrated substantial to almost perfect inter- and intra-rater agreement (AC1 = 0.61–1.00), based on commonly used agreement interpretation thresholds (Landis & Koch, 1977). This indicates that the framework can be applied reliably under typical netball performance-analysis conditions. Descriptors involving clearly observable actions, such as injured side (inter-rater AC1 = 1.00; intra-rater AC1 = 1.00), landing type (0.91; 1.00), landing balance (0.87; 0.85), playing action at injury (0.83; 1.00) and injury location variables (e.g., location on court: 0.83; 1.00), were coded consistently across reviewers, indicating strong operational clarity. Lower agreement emerged for variables requiring finer visual discrimination, particularly player movement before injury (inter = 0.43; intra = 0.60), movement direction (0.27; 0.62) and change in movement speed (0.22; 0.59), as well as for some contact-related descriptors such as contact timing/type (0.37; 0.44). These patterns likely reflect both the granularity of these categories and the constraints of single-camera match footage. Although agreement coefficients are not directly comparable across studies using different reliability statistics and coding frameworks (e.g., kappa- vs AC1-based methods), similar patterns are consistently reported in sports injury event video-analysis and injury event-classification research, with higher agreement for directly observable descriptors and lower agreement for variables requiring subjective inference or fine visual discrimination under constrained viewing conditions (e.g., Gardner et al., 2017; Hendricks et al., 2020; Mackay et al., 2023; Makdissi & Davis, 2016).

Collectively, these findings highlighted specific areas where refinement was required to optimise usability while preserving the conceptual integrity of the framework. Consistent with Mackay et al.'s (2023) guidance to adapt descriptors to study aims, and with practices in comparable frameworks (e.g., Hopkinson et al., 2022), specific targeted revisions were introduced. Notably, the movement before injury variable was simplified by consolidating five locomotion categories into three levels: walking/slow locomotion, running at low–moderate speed, and high-speed running/sprinting. This change reflected both the pilot findings and earlier concerns raised by some Delphi clinicians who anticipated difficulties reliably distinguishing detailed categories from typical netball footage. Other variables requiring subtle visual judgements, such as movement direction and speed change, were similarly streamlined to improve discriminability. In contrast, the lower agreement for contact-related descriptors and umpire decision was attributed to limitations in video clarity rather than conceptual inadequacy accordingly, no structural changes were introduced. These features are typically well recalled by injured athletes and can therefore be accurately supplemented through player self-report, an approach consistent with (Krosshaug et al., 2005) recommendation that combining complementary methods, such as video-based analysis and athlete-derived information, provides the most comprehensive representation of injury-inciting events.

Pilot testing also supported the practical usability of the NIIECS. Reviewers applied the system independently following brief, structured training, and coding times were manageable, with inter-rater coding requiring 4.45–8.22 minutes per clip (overall mean = 6.67 ± 2.21 min). Intra-rater times decreased from 7.35 ± 1.56 to 5.26 ± 0.77 minutes, indicating improved efficiency with familiarity. These findings indicate that the framework can be implemented without excessive burden, an important consideration given that injury data in many netball settings are recorded by clinicians, coaches or volunteers with limited time. With appropriate training, the NIIECS can be incorporated into existing workflows and aligned with current surveillance systems such as the PDMS, reducing duplication and supporting more consistent documentation. Its standardised categorical structure also positions the NIIECS for potential integration with emerging technologies, including athlete-tracking platforms and contextual modelling approaches informed by ecological and dynamical-systems (Smith & Bedford, 2020; Vilar et al., 2012), thereby supporting its future scalability. Together, these findings demonstrate the practical readiness of Version 1.0 for use within routine netball injury reporting and video-review workflows.

Despite these strengths, several limitations should be acknowledged. Although the Delphi panel comprised highly experienced experts across key domains, broader international representation may have expanded the perspectives included. Participant retention across rounds was also incomplete; however, all netball-specific clinical and performance practitioners participated in the second round, ensuring continuity of sport-specific insight. A small number of clinicians contributed to both the preliminary focus group and the Delphi phases, reflecting the practical challenge of recruiting specialists in netball, although anonymity and structured feedback helped minimise potential influence. The pilot testing phase was restricted to nine ankle-injury events, based on the availability and clarity of match footage from a single season. While this enabled focused assessment of visual descriptors, the small sample limits the generalisability of reliability estimates and prevented evaluation across the wider range of netball injury types. The pilot was also confined to video-based match injuries; training and non-video (athlete- or clinician-reported) contexts were not assessed, despite being key components of the NIIECS. Reliance on single end-court camera footage, typical in applied netball settings, further restricted the ability to distinguish subtle situational or movement-related features, contributing to lower agreement for some high-granularity descriptors. These limitations reflect real-world constraints rather than shortcomings of the framework itself. Further piloting across a wider range of contexts, injury types and video conditions will clarify whether additional refinements are needed.

5.4.1 Recommendations and future direction

The current study demonstrates that the NIIECS can be applied reliably and feasibly to video-based match injury events within applied netball performance support workflows. Building on this foundation, further piloting is required to evaluate reliability across the full range of injury contexts, including training injuries, injuries without an identifiable inciting event, and additional injury types. It will also be important to examine the framework's dual-mode functionality by assessing how effectively clinician records, and athlete input can complement or substitute for video when footage is missing, incomplete or difficult to derive from a single camera angle, conditions that remain common in applied netball settings. Broader implementation across elite and community environments will help establish usability under differing resource constraints and determine whether additional refinements are needed. In parallel, future work should prioritise the development and validation of the biomechanical domain of the NIIECS, enabling integration of whole-body and joint-level descriptors with the situational and behavioural information established in this chapter. The first step in this work is presented in Chapter 6, which examines expert perceptions of the practical feasibility and clarity of incorporating a preliminary set of biomechanical descriptors into the NIIECS, and identifies priorities for refinement. This represents a critical progression toward establishing a fully integrated, multi-domain inciting event classification system for netball.

5.5 Conclusion

This study developed and evaluated the first standardised framework for classifying injury-inciting events in netball, addressing major methodological gaps identified in the existing literature. Through an evidence-informed development process incorporating stakeholder input and expert consensus, the NIIECS provides a comprehensive and practical system designed to capture situational, behavioural, contextual and environmental features of injury events across match, training and non-video (athlete- or clinician-reported) contexts. Pilot testing demonstrated that the framework can be applied with acceptable reliability and in a time-efficient manner under typical netball applied conditions, supporting its current usability for clinicians, analysts and researchers. By enabling more consistent and detailed documentation of injury circumstances, the NIIECS establishes a stronger foundation for understanding injury-inciting events and informing targeted prevention strategies across all levels of the sport. With further validation across broader injury contexts and integration of the biomechanical domain, the NIIECS has the potential to become a central tool for advancing netball injury research and prevention practice.

Chapter 6: Pilot Evaluation of the Biomechanical Domain of the Netball Injury Inciting Event Classification System (NIIECS)

This chapter presents an exploratory evaluation of a preliminary biomechanical domain for the Netball Injury Inciting Event Classification System (NIIECS). Unlike the situational and behavioural domains developed in Chapter 5, the biomechanical domain required exploratory evaluation before progression to formal consensus development because the feasibility, practical applicability and utility of generic biomechanical descriptors across multiple injury types had not yet been established. This chapter therefore evaluates the applicability and interpretability of preliminary biomechanical descriptors within applied netball settings, informing priorities for their future refinement and validation. Building on the situational and behavioural domains established in Chapter 5, this work represents the next stage in the development of a fully integrated, multi-domain injury-inciting event classification system for netball.

6.1 Introduction

Understanding the biomechanical factors associated with injury is a critical component of the injury-inciting process and is central to identifying modifiable risk factors and developing more precise, inciting event-focused prevention strategies (Bahr & Krosshaug, 2005). While situational and behavioural descriptors contextualise the circumstances leading to injury, biomechanical variables provide insight into body positions, movement strategies and joint alignments that contribute to tissue loading at the moment of injury. Integrating these dimensions supports a more comprehensive account of injury causation and aligns with contemporary models, including the multi-level framework proposed by Bahr and Krosshaug (2005), which distinguishes situational/behavioural factors, whole-body mechanics and joint-level characteristics. It is also consistent with complex-systems perspectives that conceptualise injury as the emergent product of interacting behavioural, environmental and biomechanical elements (Bittencourt et al., 2016). However, despite this established importance, there remains a lack of standardised, netball-specific approaches for feasibly incorporating biomechanical descriptors into inciting-event classification in applied settings.

In sport, analysis of these biomechanical characteristics has traditionally relied on laboratory-based motion capture and force platforms to quantify joint loading, but such approaches cannot replicate real-world injury-inciting events and are impractical in applied settings (Krosshaug et al., 2005). Advanced video-based methods, such as model-based image matching, provide more realistic reconstructions but require multi-camera, high-quality footage and specialised expertise (Krosshaug & Bahr, 2005; Krosshaug et al., 2007a). Consequently, most applied injury analyses depend on visual inspection of available match or training footage. Research across multiple sports shows that trained observers can reliably identify gross biomechanical characteristics, such as landing strategy, trunk position or dynamic knee valgus, when supported by clear operational definitions and adequate video quality (Della Villa et al., 2020; Krosshaug et al., 2007a; Olsen et al., 2004; Serner et al., 2019). Similar patterns are evident in netball, where studies have described key whole-body movement features but have also highlighted the difficulty of accurately assessing detailed joint-level mechanics, even when multiple camera views are available (Belcher et al., 2022; Stuelcken et al., 2016, 2024). As outlined in Chapter 5, these challenges are compounded by inconsistent video quality and availability across competition, training and sub-elite environments. Together, these constraints highlight the need to identify which biomechanical descriptors are feasible across netball environments and to establish standardised, sport-specific biomechanical categories for all injury types. In this chapter, feasibility refers to whether biomechanical descriptors can be clearly interpreted and practically applied in typical netball settings. Consistent with the applied rationale outlined in Chapter 1, this chapter therefore adopts a pragmatic approach to inform refinement and future development of an implementable biomechanical domain within the NIIECS.

Despite these challenges, biomechanical factors remain important for characterising injury-inciting events and therefore require consideration within an inciting event classification system. However, existing netball biomechanical studies have primarily focused on specific injury types, with limited evidence to support the development of a generic biomechanical classification framework applicable across multiple injury types (Belcher et al., 2022; Stuelcken et al., 2016, 2024). Consequently, an exploratory evaluation was undertaken before progression to formal consensus development. Accordingly, this chapter presents an exploratory pilot assessment of a preliminary biomechanical domain for the NIIECS. A preliminary set of biomechanical descriptors was presented to the expert panel involved in developing the situational and behavioural domains in Chapter 5, with the aim of assessing their feasibility by identifying key challenges, areas of ambiguity and contextual factors likely to influence their interpretation and application in applied netball settings. Insights from this pilot work will directly inform priorities for subsequent consensus-based refinement and validation of a dedicated biomechanical domain within the NIIECS, supporting progression towards a fully integrated, multi-domain inciting-event classification system for netball.

6.2 Methods

6.2.1 Study design

This chapter utilised the same modified Delphi process used in Chapter 5, with the biomechanical component of the NIIECS reviewed during the first Delphi round. Ethical approval, recruitment procedures, eligibility criteria and data governance arrangements were identical to those reported previously and are therefore not repeated in detail. In brief, fifteen experts in clinical sports medicine, netball performance and sports injury research reviewed the proposed biomechanical domain via an online survey. Written informed consent and all data permissions were obtained as part of the overarching NIIECS development study (Chapter 5), with relevant ethical approval and consent documentation provided in Appendix C.

6.2.2 Development of preliminary biomechanical descriptors

The proposed biomechanical variables were informed by the systematic literature search conducted for Chapter 5, with a specific focus on studies that used video-based methods to describe biomechanical characteristics of injury-inciting events. Key work across sports (Crichton et al., 2012; Della Villa et al., 2020; Krosshaug et al., 2007b; Olsen et al., 2004; Serner et al., 2019; Waldén et al., 2015), and the three available netball-specific analyses (Belcher et al., 2022; Stuelcken et al., 2016, 2024) consistently highlighted the relevance of broad, visually observable features such as landing strategy, trunk position, knee flexion, frontal-plane collapse and foot placement during injury events. However, most existing studies focused on ACL or ankle injuries and therefore provided only limited joint-specific descriptors. To develop a more comprehensive set relevant to all injury locations, the underlying principles used in previous research, namely describing gross segment orientation and simple categorical joint positions, were extended across anatomical regions. A preliminary set of descriptors was developed covering the head/neck, trunk, upper limb (shoulder, elbow, forearm, hand/wrist) and lower limb (hip, knee, ankle/foot), with joint positions organised by anatomical plane (sagittal, frontal and transverse) where applicable. Categories reflected broad, visually recognisable orientations (e.g., flexion/extension, abduction/adduction, valgus/varus, inversion/eversion, pronation/supination, trunk rotation), along with additional lower-limb features relevant to netball such as initial ground contact and foot position relative to vertical. These descriptors were intentionally simplified to reflect what can be plausibly observed from typical netball footage and were presented to experts for review of their conceptual clarity and practical feasibility. The full set of biomechanical descriptors assessed in this pilot study is presented in Table 6.1.

6.2.3 Expert review procedure

Experts were presented with the preliminary biomechanical descriptors as part of the Round 1 Delphi survey. Unlike the situational and behavioural domains, the biomechanical variables were not evaluated for consensus. Although ratings were collected using the five-point Likert scale (1 = strongly disagree to 5 = strongly agree), these were interpreted descriptively, as the primary purpose was to obtain qualitative insights rather than determine agreement thresholds. Experts were asked to comment on the clarity and relevance of each descriptor, the practicality of identifying the proposed biomechanical features in typical netball contexts, and any factors that might influence the feasibility of using these descriptors in both video-supported and non-video (athlete- or clinician-reported) settings. They were also invited to suggest additional considerations or modifications that might improve the future development of a biomechanical domain. This qualitative feedback formed the central dataset for the pilot analysis.

6.2.4 Data Analysis

Quantitative ratings were summarised descriptively to identify descriptors that received lower perceived clarity or feasibility. Given the exploratory nature of this phase, these scores were not used to determine consensus but served only to signal areas warranting closer examination. Qualitative comments were reviewed inductively, with the aim of identifying recurring issues related to ambiguity, contextual constraints, interpretative challenges and the practical conditions under which descriptors may or may not be usable. Rather than refining items at this stage, the analysis sought to map key challenges and considerations that should inform the development of a future Delphi study dedicated specifically to establishing the biomechanical domain of the NIIECS.

Table 6.1 *Preliminary biomechanical descriptors assessed in the NIIECS pilot study*

Whole body and Joint/tissue Biomechanics	**Describe body alignment in the relevant planes at the index frame (probable injury event). Provide as much information as possible for all body areas.**
Head/Neck Injuries:	Sagittal plane: flexion, extension or neutral Frontal plane: abduction, adduction or neutral Transverse plane: external rotation, internal rotation or neutral rotation
Upper Limb Injuries:	
Shoulder:	Sagittal plane: flexion (arm moves forward), extension (backward) or neutral Frontal plane: abduction (arm moves away from body), adduction (toward body) or neutral Transverse plane: external
Elbow:	Sagittal plane: flexion (forearm towards upper arm), extension (elbow straightens) or neutral Frontal Plane: Varus (forearm deviates inward, toward midline), Valgus (forearm outward, away from midline)
Forearm:	Transverse plane: pronation (palm down), supination (palm up) or neutral

Hand/Wrist:	Sagittal plane: flexion (palm downward), extension (back of hand upward) or neutral Frontal Plane: Radial deviation (wrist moves towards thumb side) or Ulnar deviation (wrist moves towards little finger side) or Neutral
Trunk Injuries: (chest, abdomen, thoracic spine & lumbar spine)	Sagittal plane: flexion (forward bend), extension (backward bend) or neutral spine Frontal plane: lateral flexion (toward injury), lateral flexion (away from injury) or neutral (no lateral flexion) Transverse plane: rotation (toward injury), rotation (away from injury) or neutral rotation
Lower Limb Injuries:	
Hip:	Sagittal plane: flexion (thigh moves forward), extension (backward) or neutral Frontal plane: abduction (thigh moves away from midline), adduction (toward midline) or neutral Transverse plane: external rotation (thigh rotates outward), internal rotation (inward) or neutral rotation
Knee:	Sagittal plane: flexion (knee bend), extension (knee straightening) or neutral Frontal plane: Valgus (knee angled inward), Varus (outward) or neutral Transverse: Tibia external rotation (Tibia rotates outward relative to femur)
Ankle (Talocrural joint):	Sagittal plane: dorsiflexion (toes move up), plantarflexion (point downward) or neutral
Foot (Subtalar joint):	Frontal plane: inversion (sole of foot moves inward), eversion (moves outward) or neutral Transverse plane: Supination (combination of inversion, plantarflexion & forefoot adduction) and Pronation (eversion, dorsiflexion, abduction,) or neutral.
Position:	initial ground contact: hindfoot, midfoot, forefoot or combination
Position relative to vertical:	in line, in-front or behind
Additional Information:	Any information that is deemed important to describe the injury event not identified in the categories provided. Any further biomechanical description of the injury-inciting event e.g. knee injury: Knee at or close to full extension, apparent knee valgus collapse, hip internal rotation (knee injured side), direct blow to knee

Note: NIIECS = Netball Injury Inciting Event Classification System.

6.3 Results

Of the 15 experts recruited to the NIIECS consensus group, 11 (73%) completed the biomechanical rating task and 12 (80%) provided qualitative feedback. Three experts felt they were not qualified to comment. The responding experts reflected the same multidisciplinary composition as in Chapter 5, comprising researchers, clinicians and netball performance practitioners. Seven participants had primary expertise in biomechanics and/or sports injury research, with the remainder representing clinical sports medicine and netball performance domains.

6.3.1 Quantitative Summary

Overall, expert ratings indicated high levels of agreement for the biomechanical variables, with the majority receiving median scores of 4–5 and IQRs of 1, reflecting generally favourable perceptions of their conceptual clarity and feasibility. Lower and more variable ratings were observed for the broader descriptor relating to overall body alignment at the probable injury event (Index Frame), as well as the sagittal-plane and frontal-plane categories at the elbow. These descriptors showed wider dispersion in responses, including median scores of 4 with IQRs of 2 and score ranges of 2–5, indicating greater uncertainty among experts regarding the feasibility of reliably identifying these positions from typical netball footage. As this pilot was exploratory, these descriptive patterns were used to identify areas that may require closer consideration within a future Delphi study dedicated to developing the biomechanical domain of the NIIECS. The full set of summary ratings is presented in Table D1, Appendix D.

6.3.2 Qualitative Feedback

Qualitative feedback was provided by 12 experts who offered additional insight into the practical challenges of applying the preliminary biomechanical descriptors in typical netball environments. Inductive analysis identified four recurring areas of feedback: (i) ambiguity within descriptor definitions, (ii) contextual constraints related to typical netball contexts, (iii) challenges in interpreting detailed joint-level mechanics, and (iv) practical considerations affecting usability across settings. These issues are summarised narratively below, with illustrative comments presented in Table 6.2. Values shown in brackets in Table 6.2 (e.g., 8/12) indicate the number of experts (out of 12) who raised comments aligned with each theme.

6.3.2.1 Ambiguity within descriptor definitions. Experts identified several areas where descriptors required clearer definitions or boundaries. Some noted uncertainty about whether variables referred to dynamic movements or static alignments, and some actions were described as unfamiliar or difficult to recognise visually. Additional ambiguity concerned which limb should be coded, whether descriptors applied to the injured limb, the leading or contacting limb, or both sides, and when right/left specificity was required. Clarifying limb-coding rules, defining how to approach bilateral or unclear movements, and refining terminology were viewed as essential for improving consistency and feasibility.

6.3.2.2 Contextual constraints related to typical netball contexts. Experts noted that the feasibility of applying the biomechanical descriptors was highly dependent on the availability and quality of footage. Certain descriptors were viewed as more feasible in detailed video-analysis settings, but difficult to judge in standard match footage due to limited angles, player occlusion and reduced visual clarity. In settings without video, such as real-time or sideline observation, experts indicated that only broad movement characteristics could reasonably be captured, with most joint-level features deemed unobservable.

6.3.2.3 Challenges in interpreting detailed joint-level mechanics. Several descriptors were perceived as requiring greater biomechanical knowledge or more detailed guidance to support accurate classification. Experts reported difficulties in confidently interpreting specific joint-level items using the information provided, noting that clearer definitions of intended movements, reference positions and planes of motion may be required to facilitate consistent interpretation across users.

6.3.2.4 Practical considerations affecting usability. Experts also identified a number of practical constraints that may influence the usability of the biomechanical section. These included the time required to complete the full set of descriptors, the potential need for users with greater biomechanical expertise, and suggestions for enhancements such as drop-down lists, example images or simplified options to support consistent coding across diverse settings.

6.3.2.5 Summary of Key Insights. Overall, the qualitative feedback highlighted challenges related to descriptor clarity, the visibility of detailed mechanics in typical netball footage, the interpretative demands placed on users and practical considerations affecting consistent application. Together, these insights identify key areas that require refinement before progressing to a dedicated Delphi study to further define and operationalise the biomechanical domain of the NIIECS.

6.4 Discussion

The aim of this pilot study was to undertake an exploratory feasibility assessment of the preliminary biomechanical variables and categories proposed for inclusion within the Netball Injury-Inciting Event Classification System (NIIECS). By combining expert ratings with qualitative feedback, this pilot study evaluated the conceptual relevance, clarity and perceived feasibility of the preliminary biomechanical descriptors and identified key issues requiring refinement. Quantitative results showed generally favourable ratings across most biomechanical categories, with median scores typically between 4 and 5 and narrow IQRs, indicating broad support for the conceptual inclusion of biomechanical factors within the NIIECS. However, more technically demanding descriptors, particularly those involving subtle or less visually obvious joint positions, received lower and more variable ratings, prompting closer qualitative examination. The qualitative findings provided important contextual insight into the sources of this variability. Key issues related to definition clarity, contextual constraints in typical netball footage, challenges in interpreting joint-level

Table 6.2 *Summary of expert qualitative feedback on the preliminary biomechanical descriptors of the NIIECS biomechanical domain*

Theme (n/12)	Key Issues Identified	Illustrative Expert Comments
Ambiguity within descriptor definitions **(8/12)**	• Ambiguous or insufficiently defined terminology • Unclear distinctions between movements vs. alignments • Some descriptors unfamiliar or difficult to recognise visually • Uncertainty over which limb to code	"Index frame? Body alignment too vague." "I am not sure about this as it isn't a movement but an alignment…" "These movements seem less familiar and may benefit from an image." "Hard to see what the non-injured sides are doing, particularly in the lower-limb."
Contextual constraints related to typical netball contexts **(9/12)**	• Limited visibility with single-camera views • Reduced feasibility in in-game/no-video contexts • Occlusion reducing ability to view non-injured limb • Difficulty seeing subtle movements	"It is acknowledged that video footage of dynamic play has limitations for collecting or inferring biomechanical data" "These seem more doable for video analysis than in-game analysis" "I do wonder how much detail you may get…"
Challenges in interpreting detailed joint-level mechanics **(7/12)**	• Some items require additional biomechanical knowledge • Need for clearer definitions of movement planes • Uncertainty in how to classify certain joint positions	"So much detail… could imagine the biomechanics section would take some getting used to." "Unsure how it should be done exactly…"
Practical considerations affecting usability **(10/12)**	• Time burden and complexity • Variation in biomechanics expertise across users • Tool may suit more experienced practitioners • Suggestions for usability features (e.g., drop-down lists, example images)	"Maybe overload for the average person…" "Any way to include drop-downs?" "This may be more for professionals, physio's, medicals to complete?" "Future use of this type of tool with video footage may benefit from an example."

Note: NIIECS = Netball Injury Inciting Event Classification System.

mechanics and practical considerations for consistent implementation were highlighted. These findings identify priorities for refining the biomechanical domain, indicating that further conceptual development is required before progression to a formal Delphi process. Consequently, a full Delphi study lay beyond the scope of the present PhD but represents the next stage in developing a robust and implementable biomechanical component of the NIIECS.

Overall, experts supported the inclusion of biomechanical descriptors within the NIIECS, but emphasised the need for clearer definitions, simplified structures and pragmatically feasible options for both video and non-video (athlete- or clinician-reported) contexts. These findings reflect broader patterns observed in injury-inciting event research across other sports. While several frameworks describe situational and behavioural features of injury events (e.g., Aiello et al., 2023; Hendricks et al., 2020; Mackay et al., 2023), only a relatively small body of literature, primarily in ACL injury research, has attempted to operationalise joint-level biomechanics for systematic video coding. Studies in football and basketball (Della Villa et al., 2020; Krosshaug et al., 2007b; Serner et al., 2019; Waldén et al., 2015) consistently report that analysts experience difficulty judging subtle movement features, particularly transverse-plane rotations and non-injured-limb positions, from standard broadcast footage. Similar limitations have also been reported in netball video analyses, where gross movement patterns are more readily identifiable than detailed joint-level mechanics under typical footage constraints (Belcher et al., 2022; Stuelcken et al., 2016, 2024). Consistent with this evidence, experts in the present study also emphasised the need for further refinement to achieve a biomechanical structure that is both practical and informative in netball settings.

To address the challenge of incorporating biomechanical information within an applied injury-inciting event classification system , experts suggested simplifying the biomechanical domain by drawing on approaches that rely on easily recognisable movement patterns. Examples included observable-action tools such as the Salford Gait Tool (Toro et al., 2007) and structured scoring systems used in rugby tackling (Burger et al., 2016; Davidow et al., 2018; Hendricks et al., 2015; Tierney et al., 2018). Experts also proposed adopting injury-specific descriptors reported in existing research, such as those describing biomechanical characteristics of ACL and ankle injury-inciting events. However, these approaches depend on predictable, repeatable movement patterns with clearly defined “ideal” forms. Such conditions are rarely present in netball, where injuries typically occur during complex, rapidly changing, multidirectional actions that do not follow standardised motor patterns. Furthermore, although ACL and ankle studies in netball (Belcher et al., 2022; Stuelcken et al., 2016, 2024) provide valuable injury-specific insights into biomechanical features of inciting events, few comparable patterns have been sufficiently characterised across other injury types, limiting the broader application of injury-specific descriptors at present. Collectively, these findings suggest that successful integration of a biomechanical domain within the NIIECS will depend on selecting descriptors that provide meaningful biomechanical information while remaining interpretable across the diverse range of injury types encountered in netball. As the biomechanical evidence base expands, the generic biomechanical framework may be refined or supplemented with injury-specific descriptors where sufficient evidence exists. These findings therefore provide a clearer direction for future Delphi refinement of the biomechanical domain by identifying the principles that should underpin descriptor selection and development.

Expert feedback further indicated that the practical feasibility of applying these descriptors depends substantially on the availability and quality of video footage. . Previous research supports this, showing that when only single-camera footage is available, or when injuries are documented in non-video (athlete- or clinician-reported) contexts, only broad orientations or gross movement characteristics can be judged with confidence. More detailed interpretation of joint angles, limb positions and multi-planar movements requires high-quality, multi-angle footage (Belcher et al., 2022; Della Villa et al., 2020; Waldén et al., 2015). This suggests that a two-tiered biomechanical structure may be required: (i) a set of simple, video-independent descriptors that can be used for all injuries, and (ii) an extended set of more detailed descriptors applied only when clear video evidence permits. Such an approach balances inclusivity and practicality, supports consistency across diverse netball environments, and provides a clear conceptual structure for future refinement.

Although experts highlighted the limitations of manual visual estimation, emerging technologies may offer future opportunities to support biomechanical reporting in netball. Recent advances in computer-vision pose-estimation models, and wider AI-based movement-analysis approaches built on these methods, have shown increasing potential to extract broad movement characteristics from standard video footage (Schulc et al., 2024; Souaifi et al., 2025), even when the available views are not ideal. In addition, AI language tools may assist with generating more consistent descriptions of the biomechanical characteristics of injury-inciting events from clinical or lay accounts, provided they are guided by a clear, standardised classification structure. For either of these applications to be meaningful, a validated, sport-specific biomechanical framework is required to define the features of interest and ensure that any automated interpretations are accurate and clinically relevant. The refinement of the NIIECS biomechanical domain therefore not only supports current practice but also provides a necessary foundation for exploring these technological approaches in future research.

This pilot study has several limitations that should be considered when interpreting its findings. First, the feasibility ratings reflected expert perceptions rather than applied coding of injury footage; therefore, the results represent conceptual feasibility rather than demonstrated usability, which is appropriate for this preliminary, pre-Delphi stage. Second, although all experts possessed relevant professional experience, variation in biomechanical knowledge may have influenced how some descriptors were interpreted. Third, interpretations were shaped by the wording and clarity of the preliminary definitions, and some ambiguity likely contributed to variability in responses. Finally, the findings reflect the views of a single purposively sampled expert group and may not represent all potential end-users, including community-based practitioners. These limitations highlight the need for a future Delphi study to refine, clarify and operationalise the biomechanical domain of the NIIECS.

6.5 Conclusion

Overall, this feasibility pilot study demonstrates strong expert support for incorporating biomechanical descriptors within the NIIECS, while also identifying key issues that must be addressed to ensure the biomechanical domain is clear and practically usable in applied settings. The findings highlight the need for improved definition clarity, a streamlined and more intuitive descriptor structure, and explicit differentiation between information that can be identified reliably with and without video footage. Collectively, these findings demonstrate that further conceptual refinement is required before progressing to a formal Delphi consensus process. As such, this chapter represents an exploratory developmental stage that builds upon the situational and behavioural domains established in Chapter 5, and provides the conceptual and practical evidence needed to inform future Delphi refinement, validation and integration of a biomechanical domain within the NIIECS. This work also supports future integration with emerging technologies, such as computer vision and AI-assisted movement analysis, which may further enhance biomechanical reporting over time.

Chapter 7: General Discussion

7.1 Introduction

This General Discussion synthesises findings from the four studies undertaken in this thesis, integrating insights from the methodological review, applied injury surveillance, and the development and evaluation of a netball-specific injury-inciting event classification system, alongside preliminary expert consultation on the feasibility of extending the system to include biomechanical descriptors. Together, these studies address the overarching aim of the thesis, which was to strengthen the methodological foundations of injury surveillance and inciting event analysis in elite UK netball. This chapter evaluates the extent to which the thesis advanced injury surveillance methodology, improved the practical utility and comparability of injury data, developed a standardised framework for classifying injury-inciting events, and established a foundation for future biomechanical integration. It also discusses the practical and theoretical implications of these advances, critically appraises the strengths and limitations of the research, and outlines priorities for future investigation.

7.2 Summary of Findings

Despite a substantial body of netball injury research, this thesis demonstrates considerable variation in the methodological approaches used to describe injury occurrence, resulting in fragmented evidence and limited insight into injury causation, particularly the proximal circumstances of injury onset (injury-inciting events). Over the past two decades, injury research more broadly has undergone substantial methodological development, with international consensus statements and reporting guidelines establishing clearer expectations for injury surveillance and the reporting of injury-inciting events across many sports (Bahr & Krosshaug, 2005; Bahr et al., 2020). However, netball lacks a sport-specific consensus framework to guide epidemiological research and similarly has no standardised, operational approach for analysing injury-inciting events. The studies undertaken in this thesis collectively addressed these gaps by systematically evaluating existing research methodologies, implementing standardised injury surveillance within an elite UK context, and developing a sport-specific framework for analysing the circumstances surrounding injury events. The following sections integrate the key findings from this programme of work.

7.2.1 Methodological Gaps in Netball Injury Research

Recent systematic and scoping reviews of netball research have provided valuable summaries of injury patterns and broader sport science literature, including injury research (Downs et al., 2021; Whitehead et al., 2021). However, these reviews offered limited critical evaluation of the methodological approaches underpinning the sport-specific injury evidence base. In response, the structured scoping review undertaken in Study 1 provided the first comprehensive synthesis of methodologies used within netball injury research, examining study design, data sources, injury definitions, exposure measurement and approaches to injury causation. Through this process, the review identified key methodological limitations and inconsistencies across the literature and introduced evidence-informed recommendations to support more consistent, robust and comparable netball injury research in future.

Across the netball injury literature, substantial heterogeneity was evident in study design, injury definitions, exposure measurement and reporting practices, limiting comparability across studies and constraining interpretation of findings. Most studies relied on descriptive epidemiological designs, largely utilising retrospective hospital, insurance or clinic databases. While these data sources capture severe injuries at a population level, they underestimate the full extent of injuries occurring within netball-specific contexts. A smaller proportion of studies employed prospective, competition-based surveillance, with even fewer implementing ongoing, systematic injury surveillance systems aligned with contemporary best-practice recommendations (Bahr et al., 2020; Ekegren et al., 2015). Indeed, only one study has reported prospective injury data derived from an ongoing, systematic surveillance system within an elite, domestic competition, the Suncorp Super Netball league (Toohey et al., 2022). Across the wider literature, inconsistent use of injury definitions (all-complaints, medical-attention and time-loss), variable approaches to classifying injury severity, and non-standardised exposure metrics further limited interpretation of longitudinal injury patterns. Injury burden was rarely reported, and training-related and overuse injuries received minimal attention. Finally, the review highlighted a notable absence of injury surveillance research conducted within the UK, with no published studies to date examining injuries in the elite VNSL.

Beyond limitations in injury surveillance and epidemiological design, the netball injury literature has also been constrained by how injury aetiology and causation have been conceptualised and investigated. Analytic studies typically examined a limited number of isolated risk factors, often using small sample sizes and cross-sectional designs. Critically, most studies adopted reductionist approaches, treating injury development as a largely linear process and giving limited consideration to complex, multifactorial interactions between athlete characteristics, workload, environmental conditions and match-specific behaviours. This approach contrasts with contemporary injury-causation models, which conceptualise injury as the outcome of interacting factors operating across multiple temporal and contextual levels (Bittencourt et al., 2016; Fonseca et al., 2020; Meeuwisse et al., 2007; Windt & Gabbett, 2017). Most notably, the review identified a lack of standardised approaches for analysing injury-inciting events in netball. Descriptions of injury events were often based on retrospective self-report or basic categorical labels (e.g., “landing” or “collision”), which lack the detail required to inform targeted prevention strategies. At the time of the review, only two studies had employed structured video-based analyses to examine injury circumstances, highlighting a substantial gap between netball research practice and methodological advances in injury-inciting event analysis observed in other invasion and court-based sports.

While these methodological inconsistencies are not unique to netball and have been reported across a range of team sports, several sports have addressed similar challenges through the development of sport-specific surveillance frameworks and consensus-driven methodological guidance, most notably in football (Fuller et al., 2006; Waldén et al., 2023) and rugby union (Fuller et al., 2007). In contrast, equivalent methodological structures have not been established within netball, contributing to continued heterogeneity in research practice, limiting progress in understanding injury patterns and causation. In response to these gaps, Study 1 identified several methodological priorities to strengthen the netball injury evidence base. These included the need for ongoing, systematic, prospective injury surveillance systems embedded within organised netball competitions to ensure consistent capture of injury incidence, severity and burden across both match and training contexts, with alignment to IOC recommendations for injury surveillance (Bahr et al., 2020). The review also highlighted the importance of explicitly adopting multifactorial (Meeuwisse et al., 2007; Windt & Gabbett, 2017) and systems-based approaches (Bittencourt et al., 2016; Fonseca et al., 2020) to assess injury aetiology. In addition, it identified a critical need for a standardised, sport-specific framework to guide the systematic documentation of injury-inciting events. Such a framework should be capable of capturing the playing situation, player and opponent behaviours, and key biomechanical features of injury onset, in line with established inciting event models (Bahr & Krosshaug, 2005) and emerging netball-specific video-analysis descriptors (Mackay et al., 2023). Collectively, these methodological priorities directly shaped the design of the subsequent empirical studies, underpinning both the implementation of systematic injury surveillance in elite UK netball and the development and evaluation of a standardised framework for analysing injury-inciting events.

7.2.2 Injury Epidemiology in Elite UK Netball

The methodological priorities identified in the scoping review were implemented in Study 2 through a prospective injury surveillance approach within the elite UK Vitality Netball Superleague (VNSL). Following an initial pilot assessment in 2019 and disruption to the 2020 season due to the COVID-19 pandemic, a systematic injury surveillance system was implemented across all VNSL teams for the 2021 competitive season. Injury data were recorded by team medical staff using a standardised electronic platform (PDMS), with procedures aligned to contemporary international recommendations for sports injury surveillance (Bahr et al., 2020). By capturing injuries across both match and training contexts over a full competition cycle, this approach enabled consistent surveillance and provided insight into how injury incidence, severity and burden differ by exposure setting.

Building on this robust methodological foundation, Study 2 demonstrated that injury incidence was substantially higher during matches than training, with clear differences in injury characteristics between exposure contexts. Match injuries were predominantly acute and contact-related, whereas training injuries were more commonly non-contact and overuse in nature. Lower-limb injuries accounted for the majority of injuries across both settings, although their contribution to injury burden differed, with acute ankle injuries dominating match-related time-loss burden and overuse lower-leg conditions contributing disproportionately to medical-attention burden during training. Knee injuries were less frequent overall but included a small number of severe anterior cruciate ligament injuries that contributed disproportionately to injury burden across both match and training contexts. Finally, the surveillance data, considered alongside recent findings in sub-elite netball (Smyth et al., 2020), indicate that concussion potentially represents an increasing injury concern within the sport.

These patterns align with previous netball research reporting high match injury incidence, particularly during tournament or congested competition formats, and a predominance of ankle and knee injuries across playing populations (Janse van Rensburg et al., 2022; Smyth et al., 2020; Toohey et al., 2022). Although higher match than training injury rates are typical of women's team sports, match injury incidence in the VNSL exceeded that reported in several comparable sports (King et al., 2019b; López-Valenciano et al., 2021; Mayhew et al., 2021), highlighting the elevated injury risk associated with elite netball match play. Training injury incidence, in contrast, was broadly consistent with other team sports (King et al., 2019b); however, many training-related injuries were managed alongside continued match participation, and the extent to which ongoing participation while injured influences the occurrence of subsequent injuries remains unclear. More broadly, positional and scheduling influences were also evident. Players in the centre position experienced the highest injury incidence, consistent with findings from the 2019 Netball World Cup (Janse van Rensburg et al., 2022), likely reflecting sustained court exposure and high movement demands, while periods of fixture congestion were associated with elevated injury rates. These findings highlight the importance of injury surveillance systems considering injury context and outcome measures when characterising the injury problem in netball. Reliance on match-only or time-loss surveillance approaches may underestimate the impact of training-related and overuse injuries, while obscuring distinct injury patterns across exposure settings that are relevant for informing subsequent injury research and prevention efforts.

Consistent with staged models of injury prevention (van Mechelen et al., 1992), Study 2 utilised robust methods to establish the injury problem in elite UK netball. Within this model, the next stage involves understanding how injuries occur. However, as identified in the scoping review (Study 1), this stage is currently limited in netball by the absence of a standardised approach for documenting injury-inciting events, particularly with respect to situational, behavioural and biomechanical factors (Bahr & Krosshaug, 2005).

7.2.3 Development and Evaluation of a Netball- Specific Inciting Event Framework

In response to this methodological gap, Study 3 developed and evaluated the Netball Injury Inciting Event Classification System (NIIECS), a sport-specific framework for systematically documenting situational and behavioural circumstances injury-inciting events across match and training contexts, including injuries without a clear, identifiable inciting event. The NIIECS was informed by established injury causation models that conceptualise injury-inciting events as comprising the playing situation, player and opponent behaviours and whole body and joint biomechanics. This model emphasises the use of clearly defined and agreed sport-specific terminology to enable comparison across studies (Bahr & Krosshaug, 2005). In Study 3, the NIIECS operationalised the situational and behavioural components of injury-inciting events. Biomechanical descriptors were not incorporated within the framework at this stage and were examined separately as part of a subsequent pilot investigation (Study 4). The content and structure of the NIIECS were informed by synthesis of literature across multiple sports describing approaches to video-based injury event analysis, alongside recent netball-specific consensus work proposing operational descriptors and definitions (Mackay et al., 2023). These descriptors were extended to support application beyond match contexts, and the framework was designed as a flexible, dual-mode system incorporating descriptive self-report and/or video-based assessment. This approach acknowledges the inconsistent availability of video footage in applied netball settings and reduces the under-representation of training-related and gradual-onset injuries associated with match-only video analysis.

Following development of the initial framework, the NIIECS was refined through a staged consensus process. This commenced with stakeholder consultation involving key England Netball medical staff, ensuring the framework reflected applied clinical and performance contexts, before progression to a structured expert Delphi consensus process conducted in accordance with CREDES guidance (Jünger et al., 2017). The Delphi panel comprised experts across netball performance, clinical practice and injury research, supporting evaluation of the framework's conceptual clarity, relevance and usability from multiple disciplinary perspectives. This iterative, anonymous refinement process, aligned with sport video-analysis consensus approaches (Hendricks et al., 2020; Mackay et al., 2023), led to targeted modifications that strengthened descriptor definitions and overall framework structure, enhancing conceptual validity and sport-specific relevance. The first round of the Delphi process also included initial scoping feedback on proposed biomechanical descriptors, which informed the subsequent pilot investigation of the biomechanical domain (Study 4).

While the Delphi consensus process provided conceptual validity and sport-specific relevance for the NIIECS, subsequent pilot testing was undertaken to evaluate its practical usability, feasibility and reliability under applied netball conditions. Pilot testing demonstrated that the NIIECS can be applied with acceptable inter- and intra-rater reliability, particularly for clearly observable contextual, spatial and landing-related descriptors. Variables requiring finer interpretive judgement showed lower levels of agreement, reflecting both the deliberately fine level of detail incorporated within some categories and the inherent constraints of single-camera footage commonly available in netball environments. These findings are commonly reported across sports (Hendricks et al., 2016; Krosshaug et al., 2005) and highlight the inherent compromise between the level of detail required to meaningfully characterise injury-inciting events and the practical constraints of applied coding environments. Importantly, rather than undermining the overall utility of the framework, lower agreement in selected variables informed targeted refinements aimed at improving clarity and usability while preserving conceptual integrity. Furthermore, pilot testing demonstrated that the NIIECS could be applied efficiently within an applied setting, without imposing substantial additional time burden on the coder. This supports its feasibility for routine use and suggests the NIIECS has potential for integration with existing injury surveillance systems, where standardised inciting event documentation could be embedded alongside injury recording to streamline data collection and enhance the interpretability of surveillance outputs. Collectively, Study 3 establishes a practical and methodologically robust foundation for the consistent documentation of injury-inciting events in netball, addressing a critical limitation of existing surveillance approaches and providing essential scaffolding for subsequent investigation of how injuries occur, including the staged development and evaluation of biomechanical descriptors.

7.2.4 Exploratory Evaluation of the Biomechanical Domain

Study 4 extended the NIIECS by exploring the feasibility of incorporating biomechanical descriptors within an inciting event classification framework, representing the next stage in progressing from contextual description toward a more complete account of injury causation.

Consistent with multi-level injury-causation models, this pilot study recognised that while situational and behavioural factors contextualise injury events, biomechanical characteristics provide essential insight into how tissue loading may occur at the moment of injury. Through expert review, Study 4 evaluated the conceptual clarity and perceived feasibility of a preliminary set of whole-body and joint-level biomechanical descriptors designed to be applicable across injury types and netball environments.

The findings indicated broad expert support for the inclusion of biomechanical information within the NIIECS, while also highlighting important practical and methodological challenges. In particular, experts identified difficulties associated with interpreting subtle joint-level mechanics from standard single-camera match footage, ambiguity within some descriptor definitions, and variability in biomechanical expertise across potential users. These challenges mirror limitations reported in biomechanical injury analysis research across other team sports, where interpretation of joint-level mechanics from match footage has proven difficult due to restricted viewing angles, occlusion and lack of calibration, which necessitate subjective inference and limit reliability and precision (Krosshaug et al., 2007b; Olsen et al., 2004; Stuelcken et al., 2016). This reinforces the need for pragmatic expectations regarding what can be reliably observed in applied settings. Rather than attempting to resolve these challenges prematurely, Study 4 provides critical groundwork by identifying priorities for refinement and delineating the scope of a future dedicated Delphi process. In doing so, it positions the biomechanical domain as a complementary extension of the NIIECS, rather than a standalone mechanism-analysis tool, supporting a staged and methodologically coherent progression toward a fully integrated, multi-domain inciting event framework. Advances in video capture and automated movement analysis may help address some of these limitations in the future, but their meaningful application will depend on the availability of a validated, sport-specific biomechanical framework, as discussed further in Section 7.6.

Taken together, the findings demonstrate that the thesis made important methodological advances in injury surveillance and injury-inciting event analysis within netball. In relation to the methodological aims outlined in the Introduction, the programme of research improved the consistency and comparability of injury surveillance practices, enhanced the practical utility of injury surveillance data, and developed and evaluated a standardised framework for classifying injury-inciting events in netball. While the NIIECS provides a practical and methodologically robust framework for injury-inciting event documentation, broader evaluation across additional contexts would strengthen its generalisability. Similarly, the biomechanical domain represents an important foundation for future development but requires further refinement and evaluation before routine implementation. Consequently, the studies provide an important methodological foundation for future injury surveillance, injury-inciting event analysis and injury prevention research in netball.

7.3 Original Contribution to Knowledge

This thesis makes several original contributions to the netball injury evidence base by advancing methodological guidance, applied injury surveillance, and standardised approaches to injury-inciting event analysis. The scoping review (Study 1) provides the first structured, critical synthesis of methodological practices within netball injury research and translates these findings into clear, evidence-informed methodological priorities for future studies. In the absence of a netball-specific consensus statement, this review offers a practical, sport-relevant reference point for improving the consistency and comparability of injury surveillance approaches, as well as methods used to investigate injury causation and inciting events. By clearly outlining these priorities, Study 1 establishes a methodological foundation that enables future netball injury studies to be conducted and reported in a more consistent and comparable manner, thereby supporting the development of a stronger and more coherent netball injury evidence base.

Study 2 delivers the first systematic, prospective injury surveillance investigation within elite UK netball, implementing an applied surveillance system aligned with contemporary international recommendations. By capturing injuries across both match and training contexts over a full competitive season, and by reporting injury incidence, severity and burden separately by exposure setting, this study provides the first comprehensive, context-specific characterisation of the injury problem in the VNSL. Importantly, this is only the second study to report injury burden in the sport and introduces a novel operational approach to quantifying injury burden for non–time-loss injuries using medical-attention days as an alternative burden metric. This addresses a recognised limitation of time-loss–based surveillance (Bahr et al., 2020), particularly for training-related and overuse conditions that are commonly managed alongside continued participation and demonstrates how reliance on time-loss alone can underestimate the true impact of injury in elite netball. In addition, the study is one of the few in netball to explicitly report data-quality indicators, strengthening transparency and confidence in the surveillance outputs.

Study 3 developed and evaluated the first netball-specific framework for documenting injury-inciting events, the Netball Injury Inciting Event Classification System (NIIECS). The framework enables standardised capture of the situational and behavioural circumstances surrounding injury onset across match and training contexts, including injuries without a clear, identifiable inciting event. This represents a novel methodological advance that addresses a key limitation in netball injury research, where injury-inciting events have typically been described using inconsistent or overly simplistic classifications, and where training-related and gradual-onset injuries have frequently been omitted from inciting event analysis. A further original feature of the NIIECS is its flexible, dual-mode design, allowing injury-inciting events to be documented using video analysis, descriptive self-report, or a combination of both approaches. Implemented through both an Excel-based framework and a Dartfish tagging panel, the NIIECS provides a structured and guided approach to inciting event documentation that supports consistent application across varying data-availability contexts, rather than restricting analysis to match footage alone. Pilot testing demonstrated that structured inciting event documentation can be applied with acceptable inter- and intra-rater reliability and feasible coding time under typical applied netball conditions. Together, these features establish the NIIECS as a conceptually robust and practically deployable methodological framework suitable for use across a range of netball research settings.

Finally, Study 4 provides the first exploratory, staged evaluation of how biomechanical descriptors could be feasibly incorporated within a multi-domain inciting event framework for netball. By explicitly examining feasibility constraints and priorities for refinement, this study addresses a key gap in existing research, where biomechanical aspects of injury have not previously been operationalised for consistent, practical recording across injury types and applied settings. In doing so, it positions the biomechanical domain as a complementary extension of the NIIECS and establishes a coherent methodological pathway for progressing from contextual description toward more detailed investigation of how injuries occur.

Collectively, these contributions advance netball injury research by strengthening the methodological foundations of injury surveillance and by establishing a coherent, staged approach to analysing how injuries occur. Taken together, the studies move the netball injury evidence base beyond fragmented epidemiological description toward a more integrated framework that links injury occurrence, context and causal factors. In doing so, this thesis aligns netball with methodological advances seen in other team sports by providing sport-specific tools and guidance that support more consistent, comparable and prevention-relevant injury research. More broadly, it strengthens the limited evidence base available to inform injury prevention in women’s team sport (Gilhooly et al., 2023).

7.4 From Injury Description to Injury Explanation

Traditional injury surveillance has focused primarily on describing injury occurrence through measures such as incidence, severity and burden, providing an essential foundation for identifying the magnitude of the injury problem and monitoring injury patterns over time (van Mechelen et al., 1992; Bahr et al., 2020). However, surveillance alone cannot explain why injuries occur, as it provides limited insight into the interacting contextual, behavioural and biomechanical factors underpinning injury-inciting events. Contemporary complex systems models instead conceptualise injury as the product of dynamic interactions between multiple intrinsic and extrinsic factors rather than isolated risk factors (Bittencourt et al., 2016; Meeuwisse et al., 2007; Windt & Gabbett, 2017). Consequently, progressing from injury description towards injury explanation requires more comprehensive and integrated approaches to injury data collection.

The methodological developments presented in this thesis contribute towards this progression by strengthening the methodological foundations of netball injury research. Collectively, they provide more robust and standardised approaches to capturing epidemiological, contextual, behavioural and, ultimately, biomechanical information within a standardised methodological framework. Although the systematic documentation and classification of observable injury characteristics cannot, in isolation, explain the dynamic interactions that underpin injury occurrence, these approaches provide the structured and standardised data necessary to investigate these relationships more rigorously within a complex systems framework. Rather than identifying single causal mechanisms, the surveillance system and NIIECS enable epidemiological, contextual and behavioural data to be systematically integrated with other determinants of injury risk, thereby supporting progression from injury description towards injury explanation. Future research should build upon this methodological platform by integrating injury surveillance and injury-inciting event data with longitudinal information relating to athlete characteristics, previous injury, workload, physical capacity and environmental factors. As the NIIECS continues to evolve, including further refinement of the biomechanical domain, it has the potential to support increasingly comprehensive investigation of the interacting factors influencing injury occurrence and, ultimately, contribute to the development of more targeted and effective injury prevention strategies.

7.5 Practical Implications and Impact

Netball injury research has historically been characterised by inconsistent methodological approaches, reducing the comparability and applied utility of findings and contributing to a fragmented evidence base for injury prevention (Downs et al., 2021; Whitehead et al., 2021). Within the United Kingdom, this broader challenge has been compounded by the absence of a standardised, competition-wide injury surveillance system embedded within the elite domestic VNSL. Consequently, injury prevention efforts have relied on limited elite-level data and minimal systematic insight into how injuries occur in applied performance environments. In line with the overarching aim of this thesis, the methodological developments presented directly address these limitations by providing practical recommendations and frameworks to strengthen injury surveillance and inciting event analysis within elite UK netball and beyond. In particular, the scoping review (Study 1) identified clear methodological priorities for improving consistency in injury definitions, exposure metrics, outcome reporting and documentation of injury-inciting events. Together, these priorities establish a practical foundation for generating interpretable, comparable data to inform context-specific injury prevention strategies, with direct relevance for medical staff, performance analysts and governing bodies within elite netball.

The most immediate and tangible impact of this programme of work has occurred at a competition-wide governance level. Preliminary injury surveillance conducted during the 2019 VNSL season demonstrated the feasibility and applied value of systematic injury data collection within the elite competition. Although data completeness was limited, this initial work provided sufficient applied evidence to inform England Netball's decision to invest in the Performance Data Management System (PDMS), managed by the English Institute of Sport. As the governing body responsible for the VNSL, England Netball subsequently mandated injury reporting by team physiotherapists across all teams in subsequent seasons. These developments represent a clear example of research-informed change, translating early surveillance findings into structural improvements in how injury data are collected and governed within elite UK netball. The introduction of PDMS has important practical implications for the quality, consistency and sustainability of injury surveillance in the VNSL. Centralised electronic reporting supports the use of standardised injury definitions, improves data completeness, and enhances transparency in reporting practices, addressing several methodological limitations previously identified within the wider injury literature (Ekegren et al., 2015; Fuller et al., 2006, 2007). Mandatory reporting across teams further enables consistent injury capture across seasons, facilitating meaningful benchmarking of injury patterns and supporting evaluation of competition structure, scheduling demands and training practices from an injury-risk perspective.

Within this governance framework, Study 2 demonstrates that prospective, standardised injury surveillance aligned with contemporary international recommendations, such as the IOC guidelines (Bahr et al., 2020), is both feasible and informative within elite UK netball. By capturing injuries across both match and training contexts and reporting injury incidence, severity and burden as distinct but complementary outcomes, this approach provides a more complete and practically meaningful characterisation of the injury problem than has previously been available in the sport. Importantly, broadening how injury impact is quantified has clear applied value. In elite netball, many training-related and overuse injuries are managed alongside continued match participation and would therefore be underestimated or excluded by time-loss-only surveillance. The incorporation of medical-attention days as an operational measure of injury burden provides clinicians, performance staff and governing bodies with a more accurate representation of the ongoing management demands associated with injury, supporting more informed decisions around player availability, workload management and resource allocation. Together, this evidence supports the continued adoption and refinement of standardised, competition-wide injury surveillance within elite UK netball, positioning surveillance as a practical means of embedding research evidence into routine performance and medical practice.

Beyond informing surveillance design, the epidemiological patterns identified through assessment of the 2021 VNSL competition have direct practical relevance for injury prevention in elite netball. Clear differences in injury characteristics, severity and burden between match and training exposures indicate the need for context-specific prevention strategies, rather than uniform approaches applied across the training–competition cycle. In particular, the substantial contribution of acute lower-limb injuries, especially ankle and knee injuries, to match-related injury burden suggests these injuries should be a primary focus of prevention efforts, consistent with recent findings in elite Australian netball (Toohey et al., 2022). In contrast, training-related injuries were characterised by ongoing overuse and non–time-loss conditions, highlighting the importance of load management and medical oversight even when players continue to participate. The identification of concussion as a notable injury concern, consistent with findings from sub-elite netball ((Smyth et al., 2020), underscores the importance of ongoing surveillance and consistent reporting practices to ensure these injuries are appropriately captured within elite netball settings. Finally, variation in injury incidence across playing positions and periods of fixture congestion suggests that positional demands and competition structure may help inform the targeting of injury prevention strategies within elite netball.

Alongside advances in injury surveillance, the findings of this thesis have important practical implications for how injury circumstances are documented and interpreted within applied netball environments. The development and evaluation of the NIIECS provides medical staff and performance analysts with a structured and standardised framework for documenting injury-inciting events across a range of applied contexts. The framework is designed to accommodate the realities of elite netball, where video footage is not consistently available and many injuries occur during training or develop without a clearly identifiable inciting event. By enabling injury circumstances to be documented using video analysis, descriptive self-report, or a combination of both, the NIIECS allows contextual information to be captured from multiple sources, including medical staff, performance analysts, coaches and players. Importantly, the framework is designed to complement existing injury surveillance systems and can be integrated alongside routine injury reporting, rather than operating as a standalone process. Pilot testing demonstrated that this structured documentation can be applied efficiently, without imposing a substantial additional time burden on practitioners. This supports more complete and contextually rich injury documentation, enhancing the integration of inciting event information alongside surveillance outputs to inform discussions around injury risk, training design and return-to-play decision-making. Furthermore, the exploratory evaluation of the biomechanical domain informs practice by highlighting realistic expectations regarding which aspects of movement can be consistently interpreted in applied settings, providing a staged and pragmatic pathway for the future integration of biomechanical information alongside contextual injury data.

7.6 Methodological Considerations and Limitations

While this thesis advances methodological approaches to injury surveillance and inciting event analysis in elite netball, several methodological considerations should be acknowledged when interpreting the findings. These considerations primarily relate to the design and scope of the empirical studies, the nature and availability of injury surveillance and video data, and the applied constraints inherent in conducting research within elite sport environments. Such considerations are not unique to this project, but reflect wider challenges within sports injury research, particularly in balancing methodological rigour with ecological validity.

Injury surveillance during the 2021 Vitality Netball Superleague represented the first competition-wide implementation of a systematic injury surveillance system (PDMS) in elite netball, conducted using standardised data collection and reporting methods aligned with contemporary IOC recommendations (Bahr et al., 2020). This approach enabled the capture of injuries across both match and training contexts and provided a detailed and internally consistent characterisation of injury incidence, severity and burden in elite UK netball. However, the findings are derived from a single competitive season and should be interpreted with the understanding that injury patterns may vary across seasons due to changes in competition structure, scheduling density, squad composition and training practices. Indeed, the 2021 competition was conducted under COVID-19 protocols, resulting in a condensed 16-week season that may have influenced exposure patterns and recovery opportunities. In addition, injury surveillance data were obtained from seven of the eleven teams competing in the league during the 2021 season. Teams from Wales and Scotland did not participate due to data-sharing constraints, and a further two English-based teams did not contribute data because of concerns regarding the perceived reporting burden on part-time medical staff. As such, the epidemiological findings should be interpreted as a robust representation of injury patterns within the 2021 VNSL season, rather than as definitive estimates of long-term injury risk at this level of netball.

In the 2021 VNSL season, injury reporting was mandatory and conducted by team medical staff as part of routine clinical practice. While this approach reflects best practice in elite injury surveillance, it introduces potential variability related to clinical judgement, interpretation of injury definitions, and thresholds for diagnosis and return-to-play decision-making. Considerable variation in injury reporting across teams was observed, reflecting a methodological limitation consistent with challenges widely reported in applied injury surveillance research (Bjørneboe et al., 2011; Engebretsen et al., 2013). Despite high response rates and good overall data completeness among participating teams, minor, transient or overuse-related conditions may have been under-reported, particularly where athletes continued to train or compete. Such variability may have been accentuated by the semi-professional context of the VNSL, where medical staff are employed in part-time roles with limited time available for injury documentation. In addition, although full training in the use of the PDMS was provided, the 2021 season represented the first competition-wide use of the system, which may have influenced the consistency of reporting practices. Consequently, while standardised definitions, clear reporting guidance and centralised electronic data capture were implemented to support consistency, the potential for under-reporting should be considered when interpreting the findings.

In addition to variability in injury reporting practices, exposure estimation and injury attribution introduce further methodological considerations typical of applied surveillance systems. Both match and training exposure were estimated at a team level, limiting the ability to account for individual variation in playing time, training load or positional demands. Match exposure was calculated using proportionate player-hours per match multiplied by the number of matches played, while training exposure was based on average team exposure values rather than individual athlete data. Although this approach does not capture individual-level exposure, variability in reported training exposure between teams was low, suggesting broadly similar training practices across the league. Injury attribution to match or training contexts relied on the timing of symptom onset as recorded by medical staff, which may be less precise for gradual-onset (overuse) conditions where symptom development is less clearly defined. Consequently, reported injury incidence rates should be interpreted as exposure-normalised estimates at the team level rather than as precise measures of individual injury risk. While individual-level exposure data derived from workload monitoring technologies could improve precision, the approach adopted reflects common practice in applied injury surveillance and supports feasible competition-wide implementation.

Limitations also arose in relation to the development and evaluation of the NIIECS. The framework was developed through a robust, staged, expert-driven process designed to prioritise sport-specific relevance and applied usability within elite netball environments. However, as with much applied methodological research of this nature, this approach was associated with methodological considerations relating to the scope of expert input, the availability and interpretation of injury-event data, and the staged evaluation of the framework. Experts were purposively sampled to ensure depth of netball-specific clinical, performance and research expertise. While this approach strengthened the contextual validity of the framework, broader representation across disciplines, competitive levels or international settings may have introduced additional perspectives. Variation in disciplinary background, may also have influenced how some descriptors were interpreted during development and early evaluation phases.

A further methodological consideration relates specifically to the evaluation of the situational and behavioural components of the NIIECS. An initial assessment of the feasibility, reliability and practical usability was undertaken using match-based injury footage, providing an applied test under realistic performance-analysis conditions. This evaluation was, however, limited in scope and should be interpreted accordingly. Assessment focused on a small number of match-related ankle injury events for which suitable video footage was available and did not include training-related injuries, gradual-onset conditions or non-video (athlete- or clinician-reported) contexts, which form part of the broader intended application of the framework. Within this evaluation context, application of the NIIECS was influenced by the characteristics of the available footage. Match videos were derived from single end-court camera views typical of applied netball environments, with variable image quality and occasional occlusion of the injured player. These factors reduced the visibility of some situational, behavioural and movement-related features, particularly for more detailed descriptors. Consistent with this, reliability estimates were generally higher for broader categorical variables than for more granular descriptors. While the observed inter- and intra-rater agreement supports the feasibility of applying the NIIECS to match injury footage in applied settings, the findings represent an initial evaluation rather than comprehensive validation across all injury types and contexts.

Finally, certain limitations also applied to the exploratory pilot of the biomechanical domain of the NIIECS. This study was intentionally designed to assess the conceptual feasibility and interpretability of proposed biomechanical descriptors. Evaluation was based on expert judgement and reflected whether biomechanical descriptors could be meaningfully interpreted within the constraints of applied netball environments. As such, findings were influenced by variation in biomechanical expertise among contributors and the clarity of preliminary descriptor definitions. This approach was appropriate for the early stage of development and established realistic expectations regarding the potential role of biomechanical information within the broader framework. Taken together, these methodological considerations reflect the applied nature of the research and the balance required between scientific rigour and ecological validity. By explicitly acknowledging these constraints, this thesis provides a transparent basis for interpreting the findings and for guiding future work that builds on the surveillance systems and classification frameworks developed.

7.7 Future Research Directions

7.7.1 Extending injury surveillance in elite netball

Future research should prioritise longitudinal injury surveillance across multiple seasons to determine whether the injury patterns observed in the 2021 VNSL season persist under evolving competition conditions. Continued surveillance, using the PDMS and consistent systematic methods, would enable meaningful season-to-season comparisons and provide a stronger basis for evaluating the influence of changes in competition structure, scheduling demands and squad composition on injury incidence, severity and burden.. This is particularly important following the 2025 restructuring of the Netball Super League, including the reduction to eight teams and smaller squad sizes (10 rather than 12 players), which may alter player exposure, reduce rotation opportunities and increase cumulative match and training loads. Longitudinal surveillance would also enable assessment of the stability of positional injury profiles over time and provide evidence to inform competition planning, player management and targeted injury prevention strategies.

7.7.2 Understanding Injury Relationships

In addition to continued injury surveillance, future research should determine how injuries evolve over time by moving beyond isolated injury counts to examine relationships between injuries and the implications of continued participation with injury. The scoping review (Study 1) highlighted a limited focus within the netball literature on how injuries relate to one another over time and the risk of subsequent injuries. In the first netball study to assess training as well as match injuries (Study 2), the prospective surveillance demonstrated that a substantial proportion of training-related injuries were non–time-loss conditions managed alongside continued participation, raising important questions regarding whether ongoing participation with these injuries contributes to subsequent injury occurrence or cumulative injury burden. This observation aligns with wider sports injury research suggesting that non–time-loss and overuse conditions may precede more severe time-loss injuries, reflecting the dynamic nature of injury risk (Whalan et al., 2020). While competition-wide surveillance systems such as the PDMS provide an essential foundation for quantifying injury incidence and burden, they offer limited scope to capture relationships between injuries over time. Addressing this gap requires longitudinal research that integrates injury occurrence, severity, burden and exposure, alongside enhanced documentation of injury circumstances as enabled by the

NIIECS (Study 3). Such research would clarify injury trajectories, determine whether continued participation with non–time-loss injuries influences subsequent injury risk, and inform more effective load-management and injury prevention strategies within elite netball.

7.7.3 Further Evaluation and Refinement of the NIIECS

A key priority for future research is to determine whether the NIIECS can be applied consistently and feasibly across the full range of injury contexts encountered in routine netball practice. To support broader implementation, the framework requires further evaluation across a range of applied contexts to establish its practical feasibility, usability and reliability beyond the initial development and testing undertaken in this thesis. Although the framework demonstrated acceptable feasibility and reliability when applied to match-based injury events, further evaluation is required to determine whether these findings generalise across different injury types, exposure contexts and user groups.. In particular, future work should examine the application of the NIIECS to training-related injuries, gradual-onset conditions and non-video (athlete- or clinician-reported) contexts, which represent a substantial proportion of injury presentations in netball. Further applied evaluation involving clinicians, performance analysts and coaches operating under routine performance and medical workflows would support refinement of category definitions, guidance and implementation procedures. Assessing the framework's dual-mode functionality, including the integration of video-based analysis with descriptive clinical or athlete-reported information, will be important for confirming its usability under varying data-availability conditions. Collectively, this work would establish the evidence required for wider implementation of the NIIECS, ensuring that it remains both methodologically robust and practically deployable while supporting its integration alongside injury surveillance systems to enhance the consistency and interpretability of injury-inciting event documentation.

7.7.4 Development and Integration of the Biomechanical Domain

An important next step is determining which biomechanical characteristics provide clinically meaningful information while remaining feasible to collect within routine applied environments. The exploratory pilot evaluation of the biomechanical domain undertaken in this thesis provides an initial foundation for integrating biomechanical information within the NIIECS, but further development is required to support wider applied use. The pilot focused on assessing the conceptual feasibility and interpretability of proposed biomechanical descriptors, highlighting both their potential value and the practical constraints associated with consistent interpretation in typical netball environments. Future work should therefore adopt a staged development approach, beginning with a formal Delphi consensus process involving experts in netball, biomechanics, sports medicine and performance analysis. This would support refinement of descriptor definitions and agreement on a set of biomechanical variables that are clinically relevant, clearly defined and feasible to apply in practice. Applied evaluation should examine the feasibility and reliability of the refined biomechanical domain when integrated alongside the situational and behavioural components of the NIIECS. Importantly, the aim is to identify key movement and joint-level features that can be documented pragmatically to enhance interpretation of injury-inciting events within routine netball performance and medical workflows. Following validation, the biomechanical domain should be incorporated into the NIIECS and evaluated within prospective injury surveillance to determine the additional value it provides for understanding injury-inciting events and informing targeted injury prevention strategies.

7.7.5 Implementation in Partnership with England Netball

Several of the methodological developments presented in this thesis were undertaken in collaboration with England Netball and were designed to address challenges identified within current injury surveillance and injury-inciting event documentation practices. Consequently, an important next step is to determine whether the injury surveillance procedures and NIIECS can be successfully embedded within routine performance and medical practice while maintaining data quality and practitioner acceptability. Successful implementation will require more than framework development alone; it will also depond on the production of standardised guidance, user training and supporting documentation to promote consistent application by clinicians, performance analysts and other practitioners. Embedding these approaches within routine practice should be accompanied by ongoing evaluation of their feasibility, acceptability and usability. Regular user feedback from medical staff, coaches and analysts would enable iterative refinement of descriptor definitions, coding guidance and implementation procedures while ensuring that the framework remains aligned with evolving clinical practice and competition structures. Integration within existing injury surveillance workflows, rather than as a standalone process, will be essential to minimise practitioner burden and maximise long-term sustainability.

Continued collaboration between researchers, England Netball and end-users will also provide opportunities to evaluate the impact of these approaches on the quality and consistency of injury surveillance data and determine whether the additional contextual information captured by the NIIECS improves understanding of injury-inciting events and informs more targeted injury prevention strategies. Such collaborative implementation represents an important step in translating the methodological advances presented in this thesis into routine applied practice.

7.7.6 Translation Across Levels of Netball

An important priority for future research is to determine how advances in injury surveillance systems and injury-inciting event documentation can be adapted across different levels of netball without compromising data quality or practical feasibility. Resources, staffing and data availability vary considerably between elite, sub-elite, community and youth environments, creating different implementation challenges.While elite environments may support systematic surveillance and detailed injury documentation by medical staff, sub-elite, community and youth settings often rely on coaches, volunteers or athletes themselves for injury reporting. Approaches developed within this thesis should therefore be adaptable and proportionate to context, balancing data quality with feasibility. Evidence from other sports demonstrates the value of tiered, context-specific surveillance systems. For example, the Rugby Football Union has implemented a range of injury surveillance approaches across the participation pathway, enabling consistent injury monitoring while accommodating differences in staffing, expertise and infrastructure (Rugby Football Union, 2024). A similar model could be adopted within netball, whereby core injury definitions and reporting principles are retained, but data-collection methods and levels of detail are tailored to the competitive level. In this context, simplified versions of structured frameworks such as the NIIECS, alongside scalable surveillance systems, could support more consistent documentation of injury circumstances across the sport. Extending injury monitoring beyond the elite level would provide a more comprehensive understanding of injury patterns across the netball participation pathway and support the development of prevention strategies that are appropriate, equitable and evidence-informed at all levels of the game.

7.7.7 Use of Technology to Support Injury Research

Realising the potential of emerging technologies within injury surveillance will require research to determine how these approaches can reduce practitioner burden while maintaining the collection of clinically valid and meaningful data. While elite settings may support systematic surveillance and detailed inciting event documentation, sub-elite and community contexts often rely on coaches or athletes for injury reporting, amplifying feasibility constraints. In this context, advances in video capture, automated tagging and artificial intelligence (AI) could support injury surveillance and inciting event analysis in several ways. Computer-vision and pose-estimation approaches may assist with the semi-automated identification of injury-inciting events and extraction of broad movement characteristics from standard video footage, while AI-assisted coding could support more consistent classification of observable injury descriptors within frameworks such as the NIIECS (Schulc et al., 2024; Souaifi et al., 2025). However, these approaches will first require further refinement and validation of the NIIECS, particularly the biomechanical domain, to establish the movement features to be identified and ensure that automated outputs correspond to clinically meaningful descriptors. Other digital tools, including wearable workload-monitoring systems, mobile self-report platforms and integrated data systems, may further enhance injury research by supporting individual-level exposure estimation, capture of non–time-loss symptoms and linkage between injury occurrence, context and exposure. Importantly, such technologies would complement, rather than replace, clinical judgement and practitioner expertise. When integrated alongside competition-wide injury surveillance systems and structured frameworks such as the NIIECS, appropriately applied technological solutions have the potential to improve the scalability and consistency of injury documentation across levels of netball, while remaining feasible within the practical realities of applied netball environments.

7.7.8 Towards Integrated Models of Injury Aetiology and Causation

Beyond specific methodological developments, a longer-term priority for netball injury research lies in moving towards more integrated models of injury aetiology and causation. Contemporary perspectives increasingly conceptualise injury risk as dynamic and evolving, shaped by interactions between prior injury, ongoing exposure, contextual factors and the proximal circumstances of injury onset (inciting events), rather than as isolated events (Bittencourt et al., 2016; Pol et al., 2018). The scoping review undertaken in Chapter 3 highlighted growing emphasis on such integrative, systems-based approaches within the broader sports injury literature, alongside limited application of these perspectives within netball research. While addressing these complex interactions was beyond the scope of the current thesis, the methodological advances presented provide important foundations for future work adopting this perspective. In particular, the integration of systematic injury surveillance with structured documentation of injury-inciting events through the NIIECS, alongside preliminary consideration of biomechanical descriptors, creates opportunities for future research to examine injury patterns and trajectories within a more holistic framework. Progress in this area has the potential to support more nuanced understanding of injury aetiology and causation and to inform prevention strategies that better reflect the complexity of injury risk in elite netball. Realising this potential will require continued integration of injury surveillance, injury-inciting event classification and longitudinal athlete data within collaborative surveillance systems developed in partnership with governing bodies such as England Netball. Such developments would support progression from describing injury occurrence towards understanding the complex interactions underpinning injury and, ultimately, more targeted injury prevention strategies.

Collectively, these future research directions provide a pathway towards an integrated injury surveillance ecosystem in netball, where standardised surveillance, structured injury-inciting event classification, biomechanical analysis and emerging technologies work together to provide a richer understanding of injury causation across all levels of the sport. Such an approach has the potential to move injury research beyond describing injury occurrence towards identifying modifiable mechanisms and informing more precise, evidence-based injury prevention strategies.

Chapter 8: Conclusions

This thesis set out to strengthen the methodological foundations of injury surveillance and inciting event analysis in elite UK netball, a sport characterised by high injury rates but historically limited research infrastructure and inconsistent approaches to injury documentation. Through four interlinked studies, the thesis addressed this gap by critically evaluating existing netball injury research, implementing the first systematic, competition-wide injury surveillance system within the UK's elite VNSL, and developing and preliminarily evaluating the first netball-specific framework for documenting the circumstances surrounding injury events.

The scoping review highlighted substantial methodological limitations within the existing netball injury literature, including inconsistent injury definitions, limited use of prospective surveillance, and an absence of standardised approaches for examining injury-inciting events. In response to these findings, Study 2 implemented a research-led, standardised injury surveillance approach within the VNSL, aligned with contemporary international recommendations, generating the most comprehensive epidemiological dataset available for elite UK netball to date. Importantly, this work provided novel insight into training-related injury patterns and injury burden, demonstrating limitations of time-loss-only approaches and reinforcing the need for improved documentation of how and under what circumstances injuries occur. Addressing this need, Study 3 introduced the NIIECS, providing the first sport-specific framework capable of capturing situational and behavioural features of injury events across match, training and non-video (athlete- or clinician-reported) contexts. This represented a significant methodological advance for netball injury research, enabling more consistent and contextually rich documentation of injury circumstances within applied environments. Study 4 extended this work through an exploratory pilot evaluation of a biomechanical domain, demonstrating both the potential value of biomechanical information for injury interpretation and the practical constraints associated with its application in typical netball settings.

Collectively, this programme of research makes several important contributions. Methodologically, it strengthens the accuracy, consistency and interpretability of injury data within netball by establishing systematic surveillance and structured inciting event documentation as complementary approaches that can be integrated in future research and practice. Empirically, it provides new evidence describing injury patterns and burden within elite UK netball, including previously under-represented training-related injuries. Conceptually, it establishes foundations for future work that moves beyond isolated injury counts towards more integrated, context-informed understanding of injury aetiology.

While further evaluation and extension are warranted, particularly in relation to the biomechanical domain and broader application of the NIIECS across injury contexts, the work presented provides a clear and pragmatic pathway for advancing injury research across elite and community netball environments. More broadly, the methodological approaches developed within this thesis support future research examining injury trajectories, injury circumstances and contextual influences, alongside integrated models of injury risk. By improving how injuries are captured, classified and interpreted, this thesis establishes an important methodological foundation for future injury surveillance, injury-inciting event analysis and injury prevention research in netball, contributing to a more accurate and meaningful evidence base to support the health, performance and longevity of netball athletes.

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Appendices

Appendix A

Supplementary materials for Study 1: Scoping Review of Netball Injury Research (Chapter 3)

Table A1 *Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist*

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	Title - Page 42
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable) background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	Not Applicable, no standalone abstract in the Thesis
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	Page 42-43
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	Page 43
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	Not Applicable
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status) and provide a rationale.	Page 44
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	Page 43-44
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	Page 43-44
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	Page 44-45
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	Page 44-45
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	Page 44-45
Critical appraisal of individual sources of	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this	Not applicable

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
evidence		information was used in any data synthesis (if appropriate).	
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	Page 44-45
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	Figure 3.1
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	Tables 1-3
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	Not applicable
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that was charted that relates to the review questions and objectives.	Tables 3.1-3.3
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	Page 45-70
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	Page 71-77
Limitations	20	Discuss the limitations of the scoping review process.	Page 77
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	Page 77
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	Not Applicable

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.
* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.
† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).
‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.
§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

From: Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMAScR): Checklist and Explanation. Ann Intern Med. 2018;169:467–473. doi: 10.7326/M18-0850.

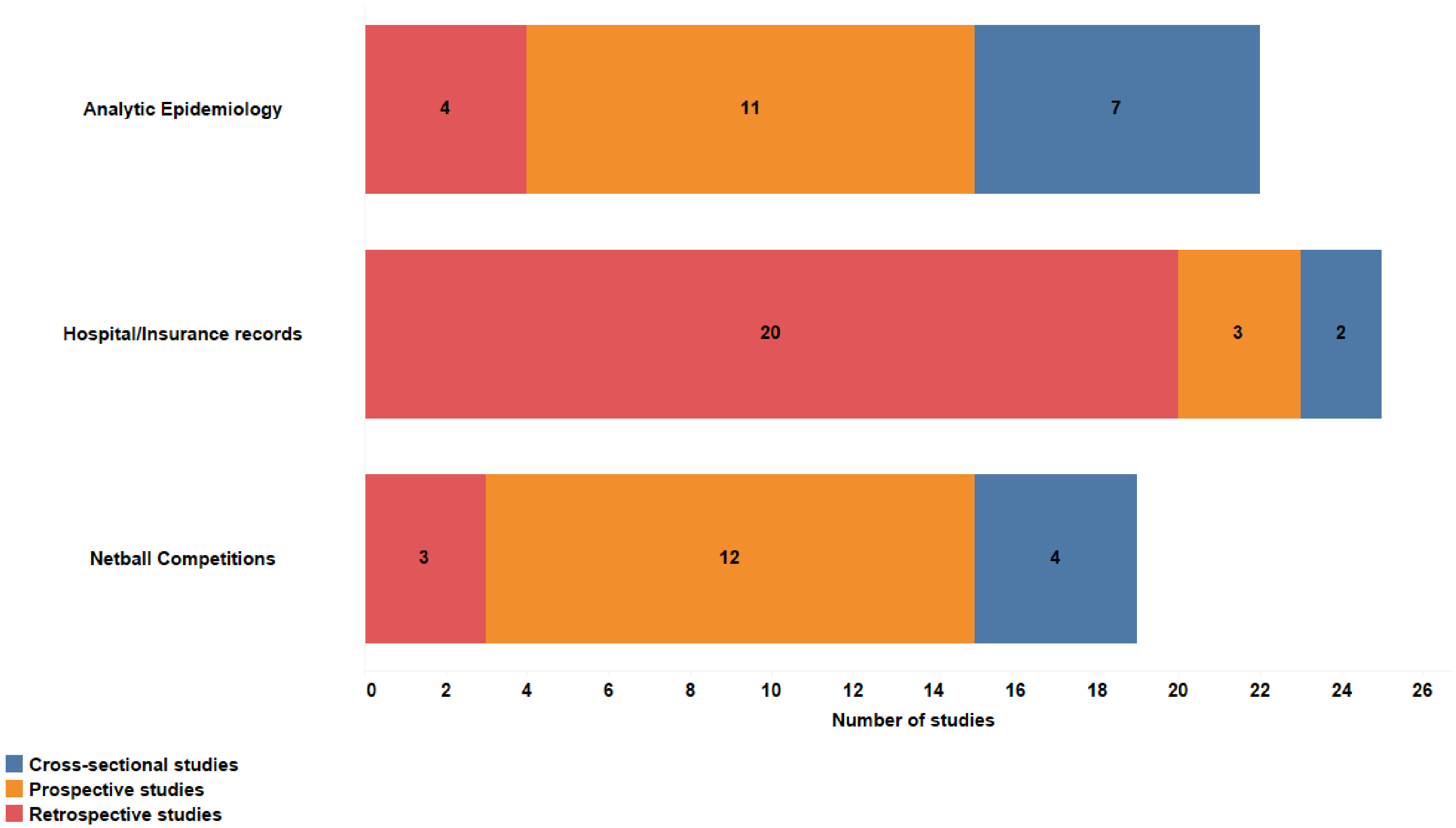


Figure A1 *Frequency of Netball Injury studies by study design*

Table A2 *Frequency of Netball injury studies by study design and year of publication*

Study Design	Pre 1998		1998–2007		2008–2018		2019–May 2024	
	n	%	n	%	n	%	n	%
Descriptive Epidemiology	**6**	**14**	**12**	**27**	**12**	**27**	**14**	**32**
Hospital/clinic records or insurance databases	3	7	7	16	7	16	8	18
Netball competitions	3	7	5	11	5	11	6	14
Analytic Epidemiology	**4**	**19**	**2**	**10**	**8**	**38**	**7**	**33**

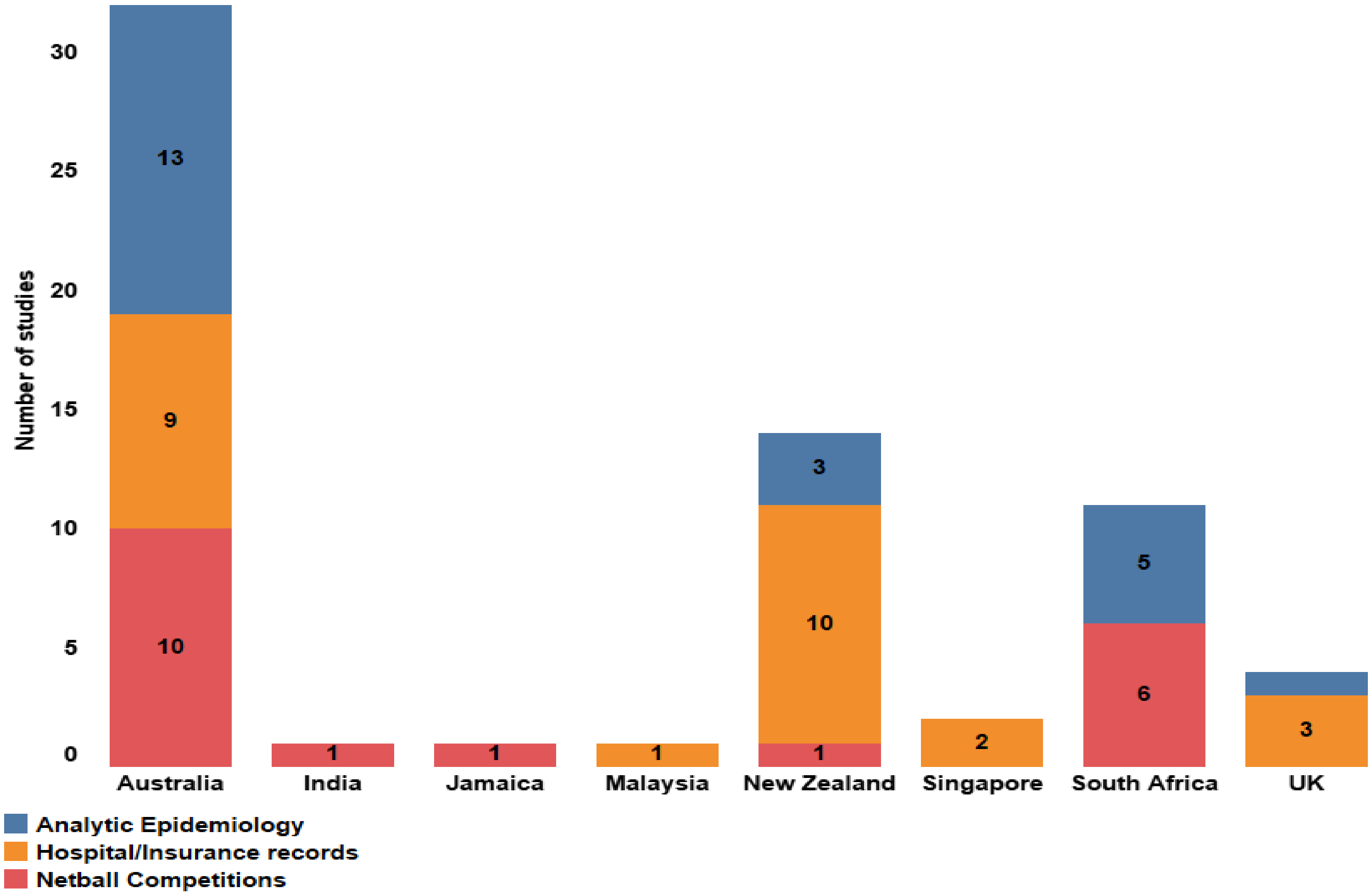


Figure A2 *Frequency of Netball injury studies by study design and country of origin*

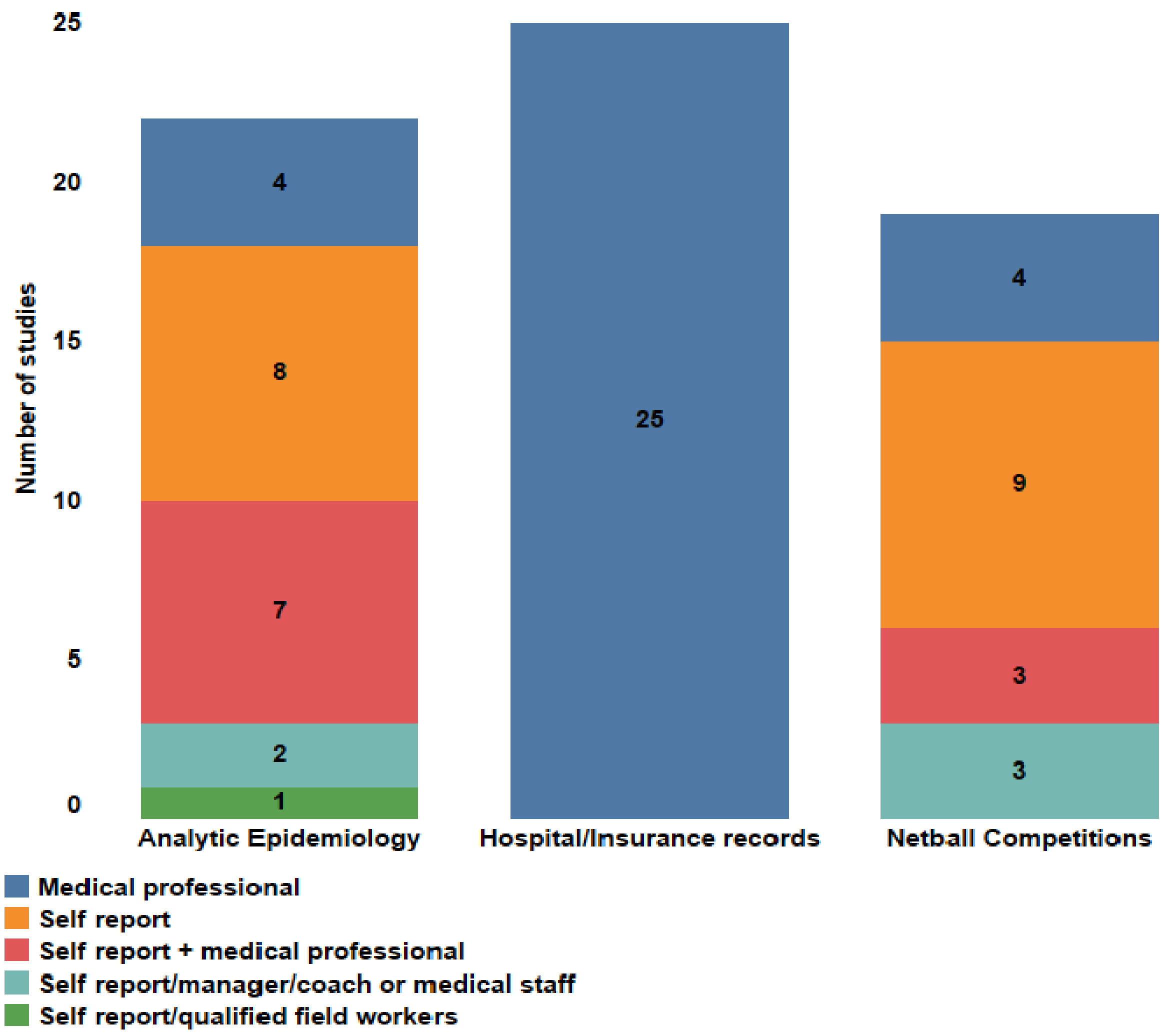


Figure A3 *Frequency of Netball injury studies by study design and data collection method*

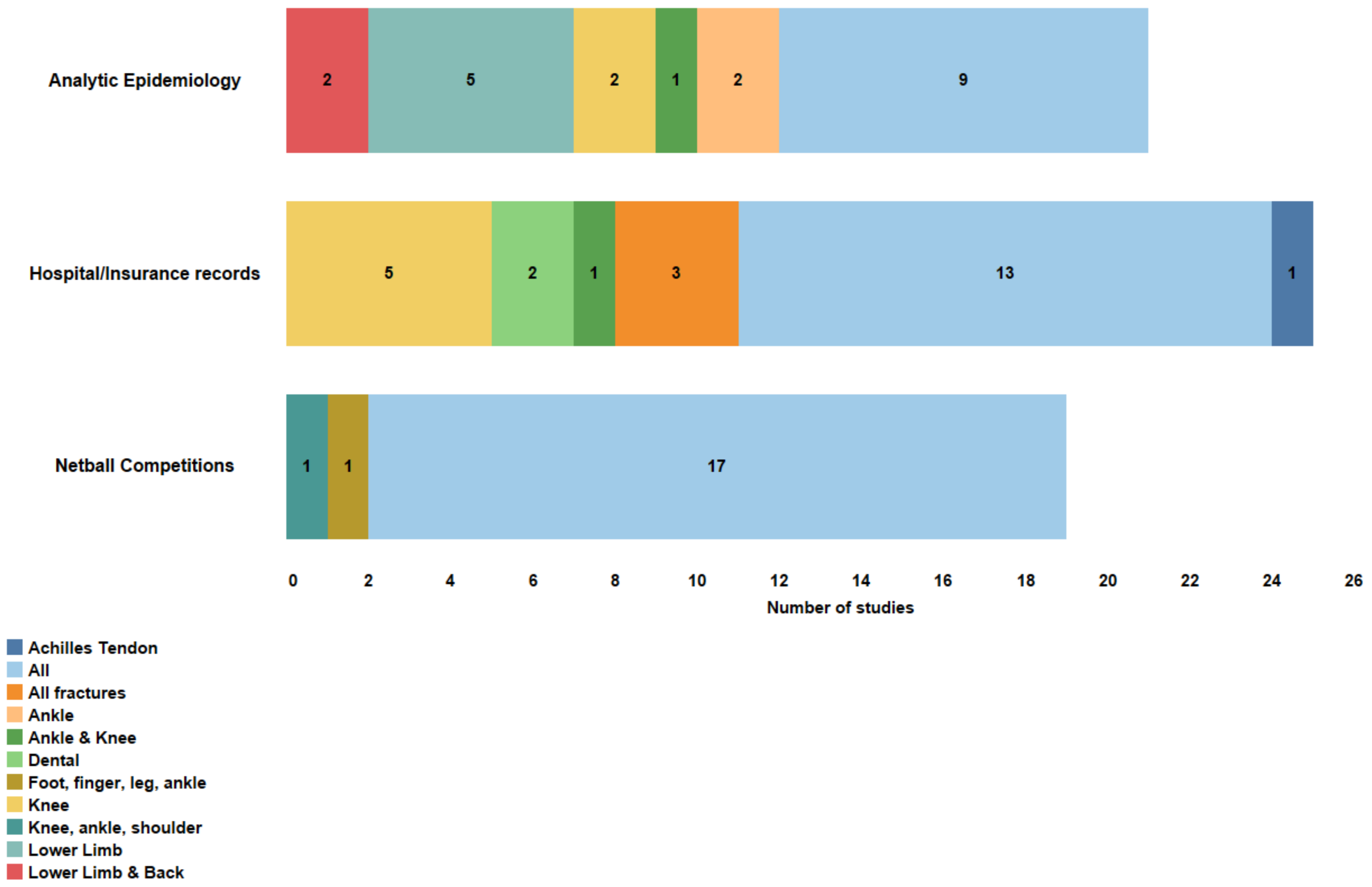


Figure A4 *Frequency of Netball injury studies by study design and body region*

Table A3 *Frequency of intrinsic and extrinsic risk factors by study design*

Risk Factors	Descriptive Epidemiology		Analytic Epidemiology	Total	
	Hospital/clinic records insurance databases	Netball Competitions			
	n	n	n	n	%
Intrinsic Factors					
Age	12	10	10	**32**	**49**
Gender	8	2	0	**10**	**15**
Ethnicity	2	1	1	**4**	**6**
Position	1	8	6	**15**	**23**
Previous injury	0	3	10	**13**	**20**
Injured side	1	1	4	**6**	**9**
Injury symptoms	0	1	0	**1**	**2**
Body composition factors:					
Height	0	1	8	**9**	**14**
Mass	0	1	8	**9**	**14**
BMI	0	1	4	**5**	**8**
Body fat percentage	0	0	3	**3**	**5**
Anatomical/biomechanical factors:					
Limb dominance	0	0	2	**2**	**3**
Limb asymmetry	0	0	1	**1**	**2**
Foot types	0	0	2	**2**	**3**
Podiatric measurements	0	0	1	**1**	**2**
Hypermobility	0	0	2	**2**	**3**
Weak joints	0	0	1	**1**	**2**
Ankle joint laxity	0	0	1	**1**	**2**
Ankle instability	0	0	1	**1**	**2**
Ankle/dorsiflexion ROM	0	0	3	**3**	**5**
Ankle isokinetic strength	0	0	1	**1**	**2**
Lower limb muscle activity	0	0	1	**1**	**2**
Frontal plane knee angle	0	0	1	**1**	**2**
Postural stability/balance	0	0	5	**5**	**8**
Lower body stiffness	0	0	1	**1**	**2**
Symmetry, dynamic mobility & local stability	0	0	1	**1**	**2**
Quadricep/Hamstring ratio	0	0	1	**1**	**2**
Movement competency	0	0	1	**1**	**2**
Physiological Factors:					
Somatotype	0	0	2	**2**	**3**
Muscular power	0	0	5	**5**	**8**
Anaerobic fitness	0	0	1	**1**	**2**
Aerobic fitness	0	0	1	**1**	**2**
Agility	0	0	2	**1**	**2**
Lower back flexibility	0	0	1	**2**	**3**
Upper & lower body & core	0	0	1	**1**	**2**
strength	0	0	1	**1**	**2**
Strength endurance	0	0	1	**1**	**2**
Speed	0	0	1	**1**	**2**

Extrinsic Factors					
Cost of injury	3	0	0	**3**	**5**
Place of injury	1	0	0	**1**	**2**
Playing with injury	0	1	0	**1**	**2**
Court location	1	1	0	**2**	**3**
No. matches played	0	1	1	**2**	**3**
Games per week	0	0	1	**1**	**2**
Playing experience	0	3	2	**5**	**8**
Level of competition	0	4	7	**11**	**17**
Footwear	0	3	1	**4**	**6**
Tape/Braces	0	2	3	**5**	**8**
Playing surface type	1	1	1	**3**	**5**
Playing surface condition	1	0	0	**1**	**2**
Weather conditions	1	1	0	**2**	**3**
Warm-up/cool-down	1	4	2	**7**	**11**
Time factors:					
Time across years	2	1	0	**3**	**5**
Time in season	0	3	3	**6**	**9**
Time following injury	0	0	1	**1**	**2**
Match half	1	0	0	**1**	**2**
Match quarter	1	6	4	**11**	**17**
Time in Quarter	0	1	1	**2**	**3**
Time playing other sports	0	0	2	**2**	**3**
Training factors:					
Training in previous year	0	0	1	**1**	**2**
Pre-season training	0	3	1	**4**	**6**
Weekly training	0	8	1	**9**	**14**
Training time/volume	0	6	2	**8**	**12**
Training modality/type	0	2	1	**3**	**5**
Training load	0	0	1	**1**	**2**
Prior training	1	0	0	**1**	**2**
Prior training duration	1	0	0	**1**	**2**
Training Preparedness	0	0	1	**1**	**2**
Treatment factors:					
Time-loss	0	2	2	**4**	**6**
Initial treatment required	0	7	2	**9**	**14**
Further treatment required	0	2	0	**2**	**3**
Referral type	0	0	1	**1**	**2**
Physiotherapist referral	1	1	0	**2**	**3**
Hospital referral	0	1	0	**1**	**2**
Surgery	2	0	0	**2**	**3**
Time to surgery	1	0	0	**1**	**2**
Return to play	1	0	0	**1**	**2**
Others:					
Number of coaches	0	1	0	**1**	**2**
Players open to new ideas	0	0	1	**1**	**2**

Appendix B

Supplementary materials for Study 2: Match and Training Injury Epidemiology in Elite UK Netball (Chapter 4)

B1 Ethical Approval Letter:

College of Health and Life Sciences Research Ethics Committee (DLS)
Brunel University London
Kingston Lane
Uxbridge
UB8 3PH
United Kingdom

www,brunel.ac,uk

18 November 2019

LETTER OF APPROVAL

APPROVAL HAS BEEN GRANTED FOR THIS STUDY TO BE CARRIED OUT BETWEEN UNTIL 01/08/21

Applicant (s): Miss Sara Horne

Project Title: Development, Implementation and validation of an injury surveillance system for elite netball.

Reference: 12619-A-Nov/2019- 21150-1

Dear Miss Sara Horne

The Research Ethics Committee has considered the above application recently submitted by you.

The Chair, acting under delegated authority has agreed that there is no objection on ethical grounds to the proposed study. Approval is given on the understanding that the conditions of approval set out below are followed:

- The agreed protocol must be followed, Any changes to the protocol will require prior approval from the Committee by way of an application for an amendment.

Please note that:

- Research Participant Information Sheets and (where relevant) flyers, posters, and consent forms should include a clear statement that research ethics approval has been obtained from the relevant Research Ethics Committee.
- The Research Participant Information Sheets should include a clear statement that queries should be directed, in the first instance, to the Supervisor (where relevant), or the researcher. Complaints, on the other hand, should be directed, in the first instance, to the Chair of the relevant Research Ethics Committee.
- The Research Ethics Committee reserves the right to sample and review documentation, including raw data, relevant to the study,

Professor Christina Victor

Chair of the College of Health and Life Sciences Research Ethics Committee (DLS)

Brunel University London

B2 England Netball Consent Letter:

ENGLAND NETBALL

A

Dear Sara,

England Netball can confirm as organisers of the Vitality Netball Superleague that you have permission to collect injury and injury risk factor data and have access to the video footage of each individual Superleague game during the 2021 and 2022 seasons for the purposes of your PhD research on Netball Injuries. Collecting the injury and risk factor data and the sharing of the video footage will be subject to gaining the consent of each franchise (team) and individual player, where required. Upon consent we understand that all individual data will remain anonymous and subject to the Data Protection Act 2018 and the research findings may be published in peer reviewed publications.

Signed

Yours sincerely

Sara Symington

Performance Director | England Netball

B3 Gatekeeper Consent Document:

College of Health, Medicine and Life Sciences
Department of Life Sciences
Division of Sport, Health and Exercise Sciences

Gatekeeper consent letter

Study Title: Assessment of Injuries in the Vitality Netball Superleague

Dear Sara

As Franchise Manager/Coach/Team Manager (delete as appropriate) of

………………………………………………………………………………………… (Team name)

Vitality Netball Superleague Squad I hereby authorise the participation of our team in the above research. I agree participant Information sheets and consent forms can be forwarded to our squad players through our designated team representative.

Signed:

Name:

Position:

Contact Details:

	Designated team contact	Team Physiotherapist
Name		
Phone Number		
Email address		

B4 Individual Player Consent Document:

College of Health and Life Sciences
Department of Life Sciences
Division of Sport, Health and Exercise Sciences

CONSENT FORM

Study Title: Development of an Injury Surveillance system for the assessment of elite netball injuries

The participant should complete the whole of this sheet		
	Please tick the appropriate box	
	YES	NO
Have you read the Research Participant Information Sheet?		
Have you had an opportunity to ask questions and discuss this study?		
Have you received satisfactory answers to all your questions?		
Who have you spoken to?		
Do you understand that you will not be referred to by name in any report concerning the study?		
Do you understand that you are free to withdraw from the study:		
• at any time?		
• without having to give a reason for withdrawing?		
Do you agree to take part in this study?		
Signature of Research Participant:		
Date:		
Name in capitals:		
I am satisfied that the above-named has given informed consent.		
Witnessed by (NSL Physiotherapist):		
Date:		
Name in capitals:		

Researcher name:	Signature:
Supervisor name:	Signature:

Table B1 *Operational definitions used in the collection of 2021 VNSL injury data*

Operational Definitions	
Injury	Injury resulting from training or match-play during the VNSL season leading to one of the following consequences: 1) medical attention or advice (from team Physiotherapist and/or other medical professional), 2) time-loss (a reduction in the amount or level of netball activity).
Match	All competitive matches during the 2021 VNSL competition.
Training	Any physical activities under the control or guidance of the 2021 VNSL team's coaching or fitness staff aimed at maintaining or improving players' netball skills or physical condition.
First Index Injury	The first injury that occurred during the 2021 VNSL competition.
Subsequent Injury	Any injury occurring after the first index injury during the VNSL competition.
Types of subsequent Injury (Hamilton et al., 2011)	Subsequent New Injury: completely different location to Index Injury
	Local Injury: same location but different type to Index Injury
	Recurrent Injury (exacerbation): same site and type as index injury but Index injury not fully healed at time of recurrence
	Recurrent Injury (reinjury): same site and type as index injury, Index injury fully healed at time of recurrence.
Acute Injury	Injury with sudden onset, resulting from identifiable, traumatic event.
Contact Injury	Acute injury resulting from contact with another player, or object.
Non-Contact Trauma	Acute injury not resulting from contact with another player or object
Overuse Injury	Injury with insidious onset and no known trauma.
Sudden Onset	Injury resulting from a specific identifiable event.
Gradual Onset	Injury without a specific identifiable event.
Injury Severity	Time-loss injuries: the total number of days lost from training and matches recorded from the date of the injury to return to full participation. 0 days lost equates to full participation the day following injury.
Severity Categories	0 days; 1-7 days; 8-28 days; >28 days
Healed Injury	A fully healed injury is one where the player has returned to full participation and/or is no longer receiving medical treatment.
Medical Attention Days	Number of days players received ongoing treatment with no impact on training or playing.
Restricted Days	Number of days players were restricted from training and/or playing
Unavailable Days	Number of days players could not participate in training or playing
Impact Duration	Number of restricted days + Number of unavailable days

Table B2 *Match and training injuries by tissue and pathology*

Tissue Type Pathology Type	Match Injuries		Training Injuries	
	n (%)	I (95% CI)	n (%)	I (95% CI)
Bone				
All	2 (2.9)	*	2 (2.9)	*
Bone stress	0		2 (2.9)	*
Fracture	2 (2.9)	*	0	
Cartilage/Synovia/Bursa				
All	4 (5.7)	*	4 (5.7)	*
Cartilage	1 (1.4)	*	0	
Synovitis/Capsulitis	1 (1.4)	*	3 (4.3)	*
Arthritis	2 (2.9)	*	1 (1.4)	
Ligament/Joint Capsule				
All	16 (22.9)	18.80 (11.15–31.03)	6 (8.6)	0.19 (0.08–0.43)
Joint sprain	16 (22.9)	18.80 (11.15–31.03)	6 (8.6)	0.19 (0.08–0.43)
Muscle/Tendon				
All	6 (8.6)	7.05 (2.87–16.06)	18 (25.7)	0.57 (0.35–0.91)
Muscle contusion	2 (2.9)	*	1 (1.4)	*
Muscle injury	1 (1.4)	*	2 (2.9)	*
Tendinopathy	3 (4.3)	*	15 (21.4)	0.47 (0.27–0.80)
Nervous				
All	3 (4.3)	*	3 (4.3)	*
Brain/Spinal cord injury	2 (2.9)	*	3 (4.3)	*
Peripheral nerve injury	1 (1.4)	*	0	
Superficial tissues/skin				
All	3 (4.3)	*	2 (2.9)	
Contusion (superficial)	0		2 (2.9)	*
Laceration	1 (1.4)	*	0	*
Abrasion	2 (2.9)	*	0	
Vessels				
All	1 (1.4)	*	0	
Vascular trauma	1 (1.4)	*	0	

Table B3 *Match and training injuries by body region, body area, diagnosis and impact*

Body Region Body area Clinical diagnosis	Match Injuries					Training Injuries				
	n (%)	**TL**	**RD**	**MA**	**ID**	**n (%)**	**TL**	**RD**	**MA**	**ID**
Head & Neck	**2 (2.9)**	**39**	**2**	**0**	**41**	**4 (5.7)**	**0**	**18**	**38**	**18**
Head	2 (2.9)	39	2	0	41	4 (5.7)	0	18	38	18
Brain/Spinal cord	2 (2.9)	39	2	0	41	3 (4.3)	0	18	37	18
Contusion	0					1 (1.4)	0	0	1	0
Upper Limb	**3 (4.3)**	**52**	**0**	**259**	**52**	**3 (4.3)**	**0**	**2**	**149**	**2**
Shoulder	1 (1.4)	0	0	16	0	2 (2.9)	0	2	56	2
Synovitis/Capsulitis	1 (1.4)	0	0	16	0	1 (1.4)	0	0	45	0
Contusion	0					1 (1.4)	0	2	11	2
Forearm	1 (1.4)	52	0	0	52	0				
Fracture	1 (1.4)	52	0	0	52	0				
Hand	1 (1.4)	0	0	243	0	1 (1.4)	0	0	93	0
Fracture	1 (1.4)	0	0	243	0	0				
Synovitis/Capsulitis	0					1 (1.43)	0	0	93	0
Trunk	**3 (4.3)**	**0**	**2**	**38**	**2**	**3 (4.3)**	**5**	**3**	**60**	**8**
Chest	0					1 (1.4)	5	0	0	5
Muscle injury	0					1 (1.4)	5	0	0	5
Thoracic spine	0					1 (1.4)	0	0	2	0
Joint sprain	0					1 (1.4)	0	0	2	0
Lumbar spine	3 (4.3)	0	2	38	2	1 (1.4)	0	3	58	3
Nerve injury	1 (1.4)	0	0	31	0	0				
Arthritis	2 (2.9)	0	2	7	2	1 (1.4)	0	3	58	3
Lower Limb	**27 (38.6)**	**558**	**141**	**950**	**699**	**25 (35.7)**	**417**	**177**	**694**	**594**
Hip/Groin	1 (1.4)	0	0	1	0	0				
Abrasion	1(1.4)	0	0	1	0	0				
Thigh	4 (5.7)	0	4	73	4	1 (1.4)	4	0	2	4
Muscle injury	1 (1.4)	0	0	15	0	1 (1.4)	4	0	2	4
Muscle contusion	2 (2.9)	0	0	5	0	0				
Vascular trauma	1 (1.4)	0	0	53	0	0				
Knee										

Laceration	4 (5.7)	208	0	265	208	5 (7.1)	288	57	27	345
Tendinopathy	1 (1.4)	0	0	7	0	0				
Cartilage injury	1 (1.4)	0	0	50	0	3 (4.3)	0	57	27	57
Synovitis/Capsulitis	1 (1.4)	0	0	208	0	0				
Joint Sprain	0					1 (1.4)	5	0	0	5
Lower leg	1 (1.4)	208	0	0	208	1 (1.4)	283	0	0	283
Tendinopathy	2 (2.9)	0	3	338	3	10 (14.3)	0	63	439	63
Ankle	2 (2.9)	0	3	338	3	10 (14.3)	0	63	439	63
Joint Sprain	15 (21.4)	350	134	255	484	6 (8.6)	125	49	176	174
Tendinopathy	15 (21.4)	350	134	255	484	4 (5.7)	125	49	104	174
Muscle contusion	0					1 (1.4)	0	0	35	0
Foot	0					1 (1.4)	0	0	37	0
Bone	1 (1.4)	0	0	18	0	3 (4.3)	0	8	50	8
Muscle/tendon	0					2 (3.0)	0	8	9	8
Abrasion	0					1 (1.4)	0	0	41	0
	1 (1.4)	0	0	18	0	0				

Appendix C

Supplementary materials for Study 3: Development of a Standardised System to Identify Injury Inciting Events in Netball (Chapter 5)

C1 Ethical Approval Letter:

College of Health, Medicine and Life Sciences Research Ethics Committee (DLS)
Brunel University of London
Kingston Lane
Uxbridge
UB8 3PH
United Kingdom

www.brunel.ac.uk

27 May 2025

LETTER OF APPROVAL

APPROVAL HAS BEEN GRANTED FOR THIS STUDY TO BE CARRIED OUT BETWEEN 01/12/2018 AND 28/08/2019

Applicant (s): Miss Sara Horne

Project Title: Development, Implementation and validation of an injury surveillance system for elite netball.

Reference: 12619-A-May/2025- 54209-2

Dear Miss Sara Horne

The Research Ethics Committee has considered the above amendment application recently submitted by you to continue to the next phase of the study, engaging a consensus group of experts to validate the classification system then to assist with reliability testing.

The Chair, acting under delegated authority has agreed that there is no objection on ethical grounds to the proposed study. Approval is given on the understanding that the conditions of approval set out below are followed:

B2 - Use of email – please ensure that you:

- can demonstrate fair and lawful collection of the email addresses used (as required by GDPR)
- use the bcc function if emailing multiple recipients
- do not use the email addresses for any purposes beyond those outlined in the PIS
- if using publicly available email addresses, let potential participants know where you obtained their address

B3 - Your revised consent form, sent through BREO correspondence, mentions those involved in the reliability testing being 'invited' to take part in the reliability testing. Please ensure that consensus group participants do not feel obligated to take part in this. All participation must be voluntary.

- **The agreed protocol must be followed. Any changes to the protocol will require prior approval from the Committee by way of an application for an amendment.**

Please note that:

- Research Participant Information Sheets and (where relevant) flyers, posters, and consent forms should include a clear statement that research ethics approval has been obtained from the relevant Research Ethics Committee.
- The Research Participant Information Sheets should include a clear statement that queries should be directed, in the first instance, to the Supervisor (where relevant), or the researcher. Complaints, on the other hand, should be directed, in the first instance, to the Chair of the relevant Research Ethics Committee.
- Approval to proceed with the study is granted subject to any conditions that may appear above.
- The Research Ethics Committee reserves the right to sample and review documentation, including raw data, relevant to the study.
- If your project has been approved to run for a duration longer than 12 months, you will be required to submit an annual progress report to the Research Ethics Committee. You will be contacted about submission of this report before it becomes due.

Professor Louise Mansfield

Chair of the College of Health, Medicine and Life Sciences Research Ethics Committee (DLS)

Brunel University London

C2 Consensus Group and Reliability Testing Consent Documents:

College of Health, Medicine and Life Sciences

Department of Life Sciences

Division of Sport, Health and Exercise Sciences

STUDY TITLE: Development of an injury surveillance system and methods for assessing injury mechanisms in elite netball

PRINCIPAL INVESTIGATOR: Sara Horne

APPROVAL HAS BEEN GRANTED FOR THIS STUDY TO BE CARRIED OUT BETWEEN 02/06/2025 AND 29/08/2025

Table 1: Consensus Group Consent

All consensus group members should complete Table 1		
	YES	NO
Have you read the Participant Information Sheet?		
Have you had an opportunity to ask questions and discuss this study?		
Have you received satisfactory answers to all your questions?		
Who have you spoken to about the study?		
Do you understand that you will not be referred to by name in any report concerning this study?		
Do you understand that:		
• You are free to withdraw from this study at any time • You don't have to give any reason for withdrawing • Choosing not to participate or withdrawing will not affect your rights • You can withdraw your data any time up to 19/07/2025		
The procedures regarding confidentiality have been explained to me		
I agree that my anonymised data can be stored and shared with other researchers for use in future projects.		
I agree to take part in this study.		
Signature of research participant:		
Print name:		
Date:		

Table 2: Reliability Testing Consent

All participants conducting reliability testing should complete Table 2		
	YES	NO
Have you read the Participant Information Sheet?		
Have you had an opportunity to ask questions and discuss this study?		
Have you received satisfactory answers to all your questions?		
Who have you spoken to about the study?		
Do you understand that you will not be referred to by name in any report concerning this study?		
Do you understand that:		
• You are free to withdraw from this study at any time • You don't have to give any reason for withdrawing • Choosing not to participate or withdrawing will not affect your rights • You can withdraw your data any time up to 16/08/2025		
The procedures regarding confidentiality have been explained to me and I agree to maintain the confidentiality of the reliability testing data.		
I agree that my anonymised data can be stored and shared with other researchers for use in future projects.		
In addition to the consensus group I am willing to take part in the reliability testing for this study.		
Signature of research participant:		
Print name:		
Date:		

C3 Initial draft of NIIECS reviewed in Round 1 of Delphi expert consensus

Netball Injury Inciting Event Classification System (NIIECS)

Background

The NIIECS has been developed as a multi-purpose tool to describe the events leading to injury (inciting event) and their biomechanical mechanisms, during training and match-play. The classification system is designed for all levels of netball and can be used either descriptively (See Excel Spreadsheet), or with video footage of the injury event (See Dartfish Tagging Panel).

NIIECS Instructions and Definitions:

- Before reading and rating the variables and categories in the Netball Injury Inciting Event Classification System (NIIECS) below, please read the separate NIIECS Instructions and Definitions document, which explains how to complete the classification system.
- Please provide any relevant feedback in the “feedback” column provided in the document, regarding the clarity of the instructions and definitions. Provide comments/suggestions regarding any changes to the definitions.
- Note, that the descriptions and definitions where applicable have been aligned with the Consensus on a netball video analysis framework paper (Mackay et al, 2023).

Netball Injury Inciting Event Classification System (NIIECS)

The following variables and categories describe the inciting event resulting in injuries related to netball playing and training activities:

- **Likert Rating:** Please rate how much you agree with the content (Coding variables and Categories) and organisation of each section. In the Likert Rating column select the appropriate rating: 1 = Strongly disagree, 2 = Disagree, 3 = Neither Agree nor Disagree, 4 = Agree, 5 = Strongly Agree or N/A = Prefer not to say.
- **Additional comments/suggestions:** Further feedback on the content and structure can be provided in the column “Additional comments/suggestions” column based on the following questions:
- Open- ended questions: Would you add any information? Would you exclude or change any information in the interest of reducing the document completion time? Would you alter any of the items in the categories? Would you reorganise the information and how? Any further suggestions for the effective implementation of the system in netball environments?

	Coding variable	Category
	General Injury Information (completed for both Training & Match Injuries)	
1	Injury Environment	Training, Match
2	Player ID code	Same code as injury surveillance player codes for cross referencing
3	Injury date	Date the injury occurred
4	Competition Name	e.g. Netball Super League
5	Competition Standard	International, Elite, Sub-elite, Education, Recreational, Other
6	Round of Competition	1-30, Semi-Final, Final, Other
7	Injury Classification	First injury (index injury), Subsequent New Injury (different location), Subsequent Local Injury (same location different type), Subsequent Exacerbation (same site & type not fully healed), Subsequent Re-Injury (same site & type fully healed)
8	Injury Mode of Onset	Acute sudden onset, Overuse sudden onset, Overuse gradual onset, Unknown
9	Injury region	Head/Neck, Upper Limb, Trunk, Lower Limb
10	Injury body area	Head, Neck, Shoulder, Upper Arm, Elbow, Forearm, Hand, Wrist, Chest, Thoracic spine, Lumbar spine, Abdomen, Hip/Groin, Thigh, Knee, Lower Leg, Ankle, Foot, unclear
11	Injured side	Left, Right, N/A
12	Injured Players Positions	The range of playing positions the injured player plays e.g. C/WA or GK/GD/WD
	Injuries with no Inciting Event	
13	Possible Causes	Cumulative microtrauma, Repetitive strain, Biomechanical imbalances, Other health conditions, Other
14	Additional Descriptive Information	Any further information relating to the possible cause of injury
	Training Injuries (completed for all Training Injuries)	
15	Training Phase	Pre-season, In-season
16	Training Session Phase	Warm-up, Main Workout, Cool-Down
17	Training Activity	Training match-play*, Sport-specific technical training, Strength training, Cardiovascular training, Speed & Agility training, Flexibility/Mobility training, Other
18	Training Environment	Indoor gym, Indoor Netball Court, Outdoors, Outdoor Netball Court, Other
19	Equipment Used	Bodyweight, Free Weights, Weights Machines, Treadmill, Stationary Bike, Rowing Machine, Cross-Trainer, Accessory equipment, Other Equipment, None

20	Training Intensity	Low, Medium, High
21	Additional training Details	Additional Training Details e.g. Drill type, specific strength exercise, type of cardiovascular training, potential injury mechanism e.g. Inefficient technique. ***If the injury occurs in training match-play additionally complete the Match Injury information.**
	Match Injuries (completed for Competition match play & Training match-play injuries)	
	Match Information & Playing situation	
22	Type of Match	Competitive Match, Training Match-Play
23	Match Environment	Indoor, Outdoor
24	Playing Surface	Wooden sprung, Wooden non-sprung, Vinyl, Artificial turf, Rubber, Concrete, Grass, Asphalt tarmac, other
25	Starting Player or Substitution	Starting Player, Substitution
26	Playing Position at injury	GS, GA, WA, C, WD, GD, GK
27	Match Quarter	Quarter 1, Quarter 2, Quarter 3, Quarter 4
28	Time in Quarter	1-5 minutes, 6-10 minutes, 11-15 minutes
29	Total Minutes Played	Total number of minutes played in game before injury
30	Team Playing Phase	Attack from centre pass, Attack following possession regain, Defence from centre pass, Defence following possession loss, Attack/Defence transition
31	Location on Court	See Diagram1
32	Location in Goal Circle	See Diagram 2
	Player/Opponent behaviour	
33	Player Movement before Injury	Stationary, Bouncing, Walking, Shuffling, Jogging, Running, High-Speed Running, Sprinting, Change of Direction, Dodge, Pivot, Twist, Jump, Turn in Air, Landing, Roll
34	Movement Direction	Forwards, Forwards left diagonal, Forwards right diagonal, Lateral left, Lateral right, Backwards, Backwards left, Backwards right, Vertical, Rotation, Unclear
35	Movement Velocity	Accelerating, Decelerating, Steady pace, N/A
36	If Jumping: Type	Two-footed take-off, Left foot take-off, Right foot take-off, Unclear, N/A

37	Height	Small, Moderate, Close to maximum, Unclear, N/A
38	If Landing: Type	Double leg landing, Split landing, Single leg left, Single leg right, Unclear, N/A
39	Balance	Balanced, Unbalanced, N/A
40	Playing Action at Injury	Shooting, Passing, Catching, Moving to get free, Marking, Off-ball Marking, Interception, Deflection, Block, Pick-up, Loose Ball, Throw-in, Defensive rebound, Attacking rebound, Other
41	Opponent Proximity to Injured Player	Within 90cm, Beyond 90cm
42	If Contact	Before injury incident, At injury incident, No Contact
43	Contact Type	Direct Contact, In-Direct Contact
		Collision with another player, Collision with umpire, Collision with ball, Collision with object (post/floor/wall), Opponent hold, push, bump, fall, arm fend
44	Referee Decision	Penalty against opponent, Penalty against player, No Penalty

Diagram 1

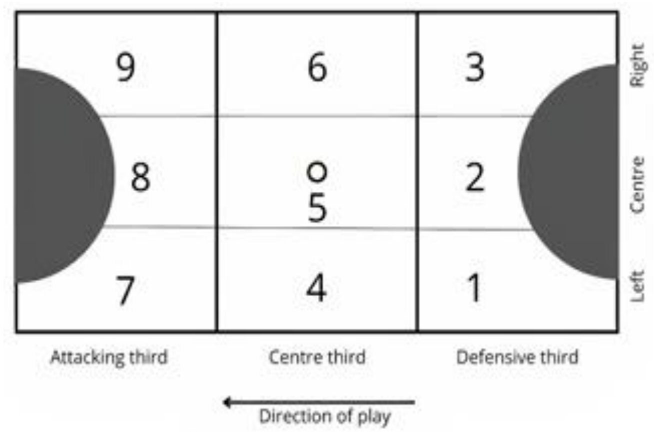
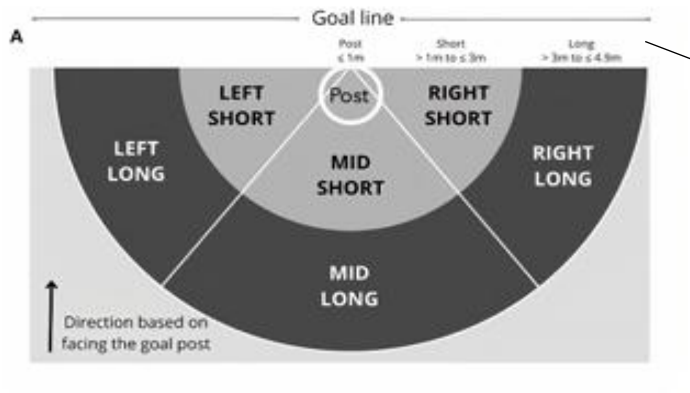


Diagram 2



Distances:
Post ≤ 1m
Short > 1m ≤ 3m
Long > 3m ≤ 4.9m

Adapted from Mackay et al. (2023)

NIIECS General Instructions and Definitions

General Instructions	
The NIIECS can be completed in two ways: either descriptively by completing the relevant sections of this document or using video footage of the injury and the example tagging/coding panel. For All Injuries complete the "General Information" spreadsheet (See Tabs at bottom of page or example tagging/coding panel). If the "Injury Environment" is "Unclear" and has no apparent, single inciting event then complete the "Injuries with no Inciting Event" spreadsheet (See Tabs at bottom of page or example tagging/coding panel), with as much information as possible. For Injuries occurring in training, complete the "Training Injuries" spreadsheet (See Tabs at bottom of page or example tagging/coding panel) For Injuries occurring in matches complete the " Match Injuries" Information spreadsheet (See Tabs at bottom of page or example tagging/coding panel) For Match-Play Training Injuries, complete the relevant information in the "Training Injuries" spreadsheet and the "Match Injuries" spreadsheet In each spreadsheet all responses require you to select the relevant options in the drop-down lists or type in the information Each Player should be given a unique ID code to anonymise data and allow cross-reference of information to injury surveillance data.	
Definitions: General Injury Information Spreadsheet (sufficient information to be able to link inciting event data with injury surveillance data)	
Injury Definition	A reportable Injury is one that occurs as a result of training or match-play in the specific Netball competition, and which led to one of the following consequences: 1) Medical attention or advice (from team Physiotherapist and/or other medical professional), 2) Time-Loss (a reduction in the amount or level of Netball activity)
Injury Analysis Method	Is the analysis of the Injury based on evaluation from video footage: Video Analysis, or is the evaluation based on a Qualitative Description only, or is it a Combination of methods?
Competition Name	Official name of the League/Tournament the injury occurred in (e.g. Netball Superleague)

Competition Standard	Level of the competition the injury occurred in: International: National representative teams Elite: Professional or semi-professional senior level, or representative at age grade. Highest level in a country with a professional or semi-professional competition Sub-elite: Tier below elite, or highest level in a country without professional or semi-professional competition Education: School, college, or university level Recreational: All competition below sub-elite
Round of Competition	Timing of injury occurrence in relation to specific competition round or tournament match
Injury Classification	First Index Injury: The first recordable injury sustained by a player during the specific competition Subsequent Injury: Any injury occurring after the index injury by the player during the specific competition Subsequent New Injury: Injury to a completely different location to Index Injury Subsequent Local Injury: Injury to the same location but different type to Index Injury Subsequent Recurrent Injury (Exacerbation): Injury to the same site and type as index injury but Index injury not fully healed at time of recurrence Subsequent Recurrent Injury (Reinjury): Injury to the same site and type as index injury, Index injury fully healed at time of recurrence
Injury Mode	Acute: Injury resulting from identifiable, traumatic event Overuse: Injury with insidious onset and no known trauma Sudden Onset: Injury resulting from a specific identifiable event Gradual Onset: Injury without a specific identifiable event
Injury Region and Body Area	Body Regions and Areas based on Orchard Sports Injury Classification System version 15 N.B. Finger/Thumb and Toe injuries are recorded under hand/wrist or foot body areas respectively in this classification system
Training Injury	Any Injury occurring during physical activities under the control or guidance of the team's coaching or fitness staff aimed at maintaining or improving players netball skills or physical condition. Training match-play injuries are recorded as training Injuries.
Match Injury	Any Injury occurring during competitive matches

Definitions: Training Injuries Spreadsheet	
Pre-Season Training	Any physical training activity conducted prior to the start of the competition in preparation for the competition
In-Season Training	Any physical training activity conducted during the competition period
Training Session Phase	Warm-up: Series of exercises performed before engaging in sports or physical activity. Main Workout: Core part of training session involving development of strength, endurance, flexibility, or technical skills. Cool-Down: Activities which help the body return to resting state, reduce heart rate and prevent stiffness and soreness
Training Activity	Training Match-Play: Match-play in a training environment that simulates real-game conditions Sport-Specific technical training: Activities designed to develop the technical skills and movements required for netball Strength Training: Exercises that focus on increasing muscular strength, endurance, and power. Can include lifting weights, bodyweight exercises, or use of other equipment e.g. resistance bands Cardiovascular Training: Exercises that focus on increasing efficiency of the heart, lungs and circulatory system and enhances endurance and stamina. Speed & Agility Training: Exercises/drills that focus on improving the ability to move quickly, change direction efficiently, and react rapidly Flexibility/Mobility Training: Exercises that focus on improving range of motion to enhance movement efficiency, reduce injury risk and support physical performance Other: Any other training activity not categorised
Equipment Used	Bodyweight: Resistance training using individual's own bodyweight as resistance. No equipment used. Free Weights: Resistance training that makes use of equipment e.g. dumbbells, barbells and weight plates, kettlebells Weights Machines: Fixed-path machines for targeted muscle groups e.g. leg press Accessory Equipment: Any other equipment used for the purpose of improving fitness or minimising injury risk: e.g. resistance bands, foam rollers, medicine balls, skipping ropes, agility ladders, battle ropes etc Other: Any other training activity not categorised e.g. Ball

Training Intensity	Low, Medium, High: Subjective description of the intensity of training performed by the player

Definitions: Match Injuries Spreadsheet	
Total minutes played	The total number of minutes played in the game before the injury
Team Playing Phase	Attack: injured player's team are in possession of the ball Defence: injured player's opposing team are in possession of ball Attack following possession regain: team has regained possession and is attacking Defence having lost possession: team has lost possession and is defending Attack/Defence transition: team has regained possession and is transitioning to attack/defence.
Location on Court	See Diagram 1: identify the zone in which the injury took place
Location in Goal Circle	See Diagram 2: if the injury occurred in the goal circle additionally identify the goal circle zone in which the injury took place
Player Movement before Injury	The player movement in the lead up to the injury: Standing: Standing with no locomotor activity of the lower limbs Bouncing: Continuous movement on the balls of the feet, simultaneously or alternately, with the feet remaining in contact or close to the ground Walking: Moving at a speed slower than jogging or running, by placing 1 foot in front of the other, never having both feet in the air at the same time Shuffling: Repeated stepping and shifting weight to one foot and planting the opposite foot closer to the stepping foot, keeping the feet close to the ground and to each other with minimal displacement of the trunk Jogging: Slow running, at a constant pace without sudden acceleration Running: Moving at a more rapid pace than walking or jogging, with elongated strides and moments in each step where both feet are off the ground High-Speed running: Moving at a more rapid pace than running, but below maximal speed Sprinting: Running at near- maximal, or maximal speed Change of Direction: Whole body movement with a sudden change in direction of travel Dodge: Deceptive change(s) in direction Pivot: A movement where the player with the ball swivels either on the heel or on the ball of the landing

	foot while this foot maintains contact with the ground Twist: A movement where a player rotates the body but the foot (or feet) remains fixed (i.e., do not swivel) Jump: A movement of vertical and/or horizontal displacement taking off from one or both feet Turn in air: Player rotates whole or part of the body while in the air to land facing a different direction Landing: Returning to the ground following a jump on one or both feet Roll: A movement of rotations where the player turns their back to the opposition player to move in a different direction
Movement Direction	The movement direction relative to the player
Movement Velocity	Accelerating: The player demonstrates a visible increase in velocity Decelerating: The player demonstrates a visible decrease in velocity
Movement Intensity	Low, Medium, High: Subjective description of the intensity of movement performed by the player
Jump Type	If the player was in the act of jumping when the injury occurred which foot or feet does the player take-off from: Two-footed, Left foot, Right foot
Jump Height	If the player was in the act of jumping when the injury occurred what was the subjective height the player jumped: Small, Moderate, Close to maximum
Landing Type	If the player was in the act of landing when the injury how did they land: Double leg landing: Landing simultaneously on two feet, at or closer than shoulder width apart, following a jump Split landing: Landing simultaneously on two feet, further than shoulder width apart, following a jump Single leg (left or right) landing: Landing on one foot following a jump
Landing Balance	If the player was in the act of landing when the injury occurred how balanced was the player: Balanced, Unbalanced
Playing action at Injury:	Netball technical playing action at time of injury: Shooting: The player is directing the ball towards the ring in an attempt to score a goal; GS and GA only Passing: The player is releasing the ball towards another player, one or two-handed Catching: The player is receiving the ball, one or two-handed Moving to get free: The player is moving in an attempt to get away from an opponent Marking a Player: The player is actively defending another player who is in possession of the ball

	Off-ball marking: The player is actively defending a player who is not in possession of the ball Interception: The player takes possession via a catch, or a deflection and a pick- up, from an opposition pass Deflection: The player touches the ball and changes the course, motion, or speed of the ball Block: The player deflects a shot that prevents a goal: GK or GD only Pick-up: The player secures possession of a loose ball Loose ball: The player is attempting to gain possession of the ball in neither team possession but still in play Throw-in: The player is passing from outside of the court to restart play, after the ball has been deemed out of court by the umpire Defensive rebound: The player is regathering the ball after an unsuccessful shot by the opposition Attacking rebound: The player is regathering the ball after an unsuccessful shot on goal
Contact	Did contact impact the injury? If Yes: Before injury incident or At injury Incident, If No: No-Contact: No contact with another individual or object at the time of the injury.
If Contact: Contact Type	If the player was contacted at the injury incident identify the type of contact: Direct Contact: Direct blow to injured body part Indirect Contact: Contact to any other body region other than the injured body part Collision with another player, Collision with umpire, Collision with ball, Collision with object (post/floor/wall), Opponent hold, push, bump, fall, arm fend
Referee Decision	Did the injury event lead to a referee decision i.e. penalty? Whom was the penalty against: player or opponent?

Table C1: *Delphi consensus results for each category of the Netball Injury Inciting Event Classification System (NIIECS)*

Variable	Category	Round 1 Agreement (%)	Round 2 Agreement (%)	Median (IQR)	Round Achieved Consensus	Summary Changes Round 1	Summary Changes Round 2
General Injury Information (completed for both Training & Match Injuries)							
Injury Environment	Training, Match, Other (specify), Unknown	93%		5.0 (5–5)	1	Other (specify) and Unknown added. No other changes	
Player ID code: Core ID + season extension	Assign each player a consistent anonymised ID (e.g., P001) with an added season code (e.g., P001-2025), same as existing surveillance identifiers.	100%		5.0 (5–5)	1	Coding system updated and clear instructions provided	
Injury date	Date the injury occurred	100%		5.0 (5–5)	1	No change	
Competition Name	e.g. Netball Super League	80%		5.0 (5–5)	1	Definition updated to clarify how to record training injuries both in and out of competition periods	
Competition Standard	International, Elite, Sub-elite, Education, Recreational, Other (specify), Unknown	93%		5.0 (5–5)	1	“Other (specify)” and “Unknown” added. Examples and explanatory notes added in the “Instructions and Definitions” to improve clarity and ensure consistent recording across contexts	
Stage of Competition/ Season	Pre-Season, Regular Season, Play-offs/Semi-finals/Final, Off-Season, Other (specify), Unknown	67%	100%	5.0 (5–5)	2	Replaces “Round of Competition,” combining previous “Training Phase” detail and adding “Off-Season” to clarify timing within the competitive calendar	
If Regular	Round 1-30, Other (specify)	67%	100%	5.0 (4–5)	2	Replaces “Round of	

Variable	Category	Round 1 Agreement (%)	Round 2 Agreement (%)	Median (IQR)	Round Achieved Consensus	Summary Changes Round 1	Summary Changes Round 2
Season Injury – Round Number						Competition." Completed only if "Regular Season" is selected to specify the exact round of injury	
Injury Number	Used with Injury Classification to describe injury relationships. New injuries are numbered sequentially (1, 2, 3), with suffixes for recurrences (1a, 1b, 2a, 2b). The first index injury each season is always "1"		83%	5.0 (5–5)	2	Added to support clear identification of injury relationships when used with Injury Classification (see "Instructions and Definitions" for details)	
Injury Classification	First injury (index injury), Subsequent New Injury (different location), Subsequent Local Injury (same location different type), Subsequent Exacerbation (same site & type not fully healed), Subsequent Re-Injury (same site & type fully healed), Unknown	80%		5.0 (5–5)	1	Clear definitions and examples are provided to show the process of coding the relationship between injuries in the "Instructions and Definitions"	
Injury Mode of Onset	Acute sudden onset, Overuse sudden onset, Overuse gradual onset, Unknown	73%	100%	5.0 (5–5)	2	No change. Categories retained for consistency with the IOC Consensus Statement (Bahr et al., 2020). Distinguishing "overuse–sudden" from "overuse–gradual" enables differentiation between acute symptom flare-ups (e.g., Achilles rupture) and progressively developing injuries (e.g., patellar tendinopathy), offering	

Variable	Category	Round 1 Agreement (%)	Round 2 Agreement (%)	Median (IQR)	Round Achieved Consensus	Summary Changes Round 1	Summary Changes Round 2
						important clinical and epidemiological insight. The "Unknown" option allows provisional coding pending clinical clarification.	
Injury Region	Head/Neck, Upper Limb, Trunk, Lower Limb	73%				Removed from tool – as not required	
Injury Body Area	Head, Neck, Shoulder, Upper Arm, Elbow, Forearm, Hand, Wrist, Chest, Thoracic spine, Lumbar spine, Abdomen, Hip/Groin, Thigh, Knee, Lower Leg, Ankle, Foot, Unclear	87%		5.0 (5–5)	1	No change	
Injured Side	Right, Left, N/A, Unknown	100%		5.0 (5–5)	1	No change	
Dominant Side	Right, Left, N/A, Unknown		100%	5.0 (4–5)	2	Added to support identification of dominant side	Separate "Hand" and "Leg Dominance" sections combined into one section. Definition updated for clarity
Injured Player Position	GS, GA, WA, C, WD, GD, GK	60%				Removed, as this information is available from injury surveillance data on player position familiarity	
Any Further Descriptive Information			100%	5.0 (5–5)	2	General descriptive section added	

Variable	Category	Round 1 Agreement (%)	Round 2 Agreement (%)	Median (IQR)	Round Achieved Consensus	Summary Changes Round 1	Summary Changes Round 2
Injuries with no Inciting Event							
Possible Causes	Cumulative Tissue Overload/Microtrauma, Training Load Error (too much/too soon), Biomechanical/anatomical factor, Medical/health-related contributors, Other (specify), Unknown	80%		5.0 (5–5)	1	Updated to capture underlying causes of overuse injuries, reflecting pathophysiological models (cumulative microtrauma, repetitive strain, biomechanical imbalance) and accommodating mechanical or systemic factors. Added “Other (specify)” and “Unknown” categories.	
Additional Descriptive Information	(Describe any contextual or individual factors that may have contributed to the injury, beyond the predefined categories (e.g., pain during progressive sprint load, gradual onset of Achilles soreness). If unknown, leave blank	80%		5.0 (5–5)	1	Reworded and example provided	
Training Injuries (completed for all Training Injuries including netball-specific drills, conditioned match-play, or full training match-play)							
Training Injury Information & Training Situation							
Training Phase	Pre-season, In-season	93%				Removed and merged into “Stage of	

Variable	Category	Round 1 Agreement (%)	Round 2 Agreement (%)	Median (IQR)	Round Achieved Consensus	Summary Changes Round 1	Summary Changes Round 2
						Competition/Season” within the General Information section to provide consistent classification across all injury types.	
Training Session Phase	Warm-up, Main Workout, Cool-Down, Unknown	87%		5.0 (5–5)	1	“Unknown” added. No further changes	
Training Activity	Strength training, Cardiovascular conditioning, Speed & Agility training, Flexibility/Mobility training, Neuromuscular/Proprioceptive training, Sport-specific technical drill (Unopposed), Sport-specific opposed drill, Conditioned match-play, Full training match-play, Other (specify), Unknown	100%		5.0 (5–5)	1	Activity categories updated to include the range of netball specific activities Other (specify) and Unknown added	
Additional Training Details	Further qualitative description of specific exercise, drill or activity being performed at time of injury. *See examples in “Instructions and Definitions”	80%		5.0 (5–5)	1	Section moved to follow on from “Training Activity” and expanded to capture specific exercises, drills, or activities at the time of injury, with examples of training types. Training intensity is reflected through load, duration, speed, and work-to-rest ratio.	
Training Environment	Indoor gym, Indoor Netball Court, Outdoors, Outdoor Netball Court, Other (specify), Unknown	93%		5.0 (5–5)	1	Other (specify) and Unknown added. No other changes	
Training Surface	Wooden sprung, Wooden non-sprung, Vinyl, Artificial turf, Rubber, Concrete, Grass,	92%		5.0 (5–5)	1	Added to this section (identical to Match Injury categories; previously achieved consensus,	

Variable	Category	Round 1 Agreement (%)	Round 2 Agreement (%)	Median (IQR)	Round Achieved Consensus	Summary Changes Round 1	Summary Changes Round 2
	Asphalt tarmac, Other (specify), Unknown					therefore not re-rated).	
Equipment Used	None (bodyweight only), Ball, Free Weights, Weights Machines, Accessory Equipment, Cardio Machine, Other (specify), Unknown	73%	83%	5.0 (5–5)	2	Retained and modified (added “Ball”). Provides valuable contextual information on training environment and equipment-related load exposure; supports interpretation of injury mechanisms.	
Training Intensity	Low, Medium, High	53%				Removed due to subjectivity and integrated into “Additional Training Details” to capture activity-specific intensity in a more descriptive, contextual format	
Any further Descriptive Information	Any further descriptive Information (If the "Other (specify)" option was selected provide detail here)		100%	5.0 (5–5)	2	Added to capture any additional information	
Netball-specific Training Injury Information (For all netball-specific training injuries complete the following categories)						Added. See summary below*. The netball-specific Training Injury Information section mirrors match variables but includes only training-relevant items, reflecting key types (unopposed/opposed drills, conditioned and full match-play). Match-only variables were removed, and the section reordered accordingly	

Variable	Category	Round 1 Agreement (%)	Round 2 Agreement (%)	Median (IQR)	Round Achieved Consensus	Summary Changes Round 1	Summary Changes Round 2
Player Movement before Injury	Stationary, Bouncing, Walking, Shuffling, Jogging, Running, High-Speed Running, Sprinting, Change of Direction, Dodge, Pivot, Twist, Jump, Turn in Air, Landing, Roll, Other (specify), Unknown	92%		5.0 (5–5)	1	Added Other (specify). No other changes	
Movement Direction	Forwards, Forward left diagonal, Forward right diagonal, Lateral left, Lateral right, Backwards, Backward left, Backward right, Vertical, Rotation, Other (specify), Unclear	92%		5.0 (5–5)	1	Added Other (specify). No other changes	
Change in Movement Speed	Accelerating, Decelerating, Steady pace, N/A, Unclear	83%		5.0 (5–5)	1	Title changed from “Movement Velocity” to “Change in Movement Speed”	
If Jumping: Type	Two-footed take-off, Left foot take-off, Right foot take-off, Unclear	83%		5.0 (5–5)	1	No Change	
If Jumping: Relative Elevation	Minimal Elevation (feet just off ground), Moderate Elevation (noticeable lift typical of routine play), High Elevation (substantial elevation), Unclear	33%	91%	5.0 (4–5)	2	Renamed “Relative Elevation.” Categories revised to remove subjective terms (e.g., “close to maximum”) and rate height contextually by visible elevation from the ground. Examples are provided in the “Instructions and Definitions”	
If Landing: Type	Double leg landing, Split landing, Single leg left, Single leg right, Unclear	83%		5.0 (5–5)	1	No Change	

Variable	Category	Round 1 Agreement (%)	Round 2 Agreement (%)	Median (IQR)	Round Achieved Consensus	Summary Changes Round 1	Summary Changes Round 2
If Landing: Balance	Balanced, Unbalanced, Unclear	85%		5.0 (5–5)	1	Clear definitions added in "Instructions and Definitions"	
If Landing: Footwork Violation	Yes, No, Unclear		92%	4.5 (4–5)	2	Added to record any footwork violation or irregularity at the time of injury, distinguishing biomechanical instability from technical or decision-making errors	
Playing Action at Injury	Shooting, Passing, Catching, Trying to get free, Marking, Off-ball Marking, Interception, Deflection, Block, Pick-up, Loose Ball, Throw-in, Defensive rebound, Attacking rebound, Other (specify), Unknown	91%		5.0 (5–5)	1	"Other (specify)" and "Unknown" added. No other changes	
Contact: Timing and Type	No Contact, Contact before injury – Indirect, Contact at Injury – Direct, Contact at Injury – Indirect, Unclear	83%		5.0 (5–5)	1	"Contact" and "If Contact" have been combined into one category "Contact: Timing and Type" for clarity and efficiency	
If Contact: Nature of Contact	Collision with another player, Collision with umpire, Collision with ball, Collision with object (post/wall/floor), Opponent action (hold/push/bump/fall/arm fend), Other (specify), Unclear	92%		5.0 (5–5)	1	New Title: "Nature of Contact" "Other (specify) added	
If Contact: Support Phase	Double-Leg Stance, Single-Leg Stance, Airborne, On the ground, Unclear		92%	5.0 (4–5)	2	Added to record body support position at contact, influencing balance, stability, and force absorption through the lower limbs	Category title changed from "If Contact: Stance" to "If Contact: Support Phase"

Variable	Category	Round 1 Agreement (%)	Round 2 Agreement (%)	Median (IQR)	Round Achieved Consensus	Summary Changes Round 1	Summary Changes Round 2
If Contact: Player Anticipation	Yes, No, Unclear		83%	4.5 (4–5)	2	Added to record whether contact was anticipated, reflecting behavioural and neuromuscular readiness that influences muscle activation, joint stiffness, and contact-related injury risk	
If Relevant: Playing Situation (e.g. conditioned or full match-play) complete the following categories)							
Playing Position	GS, GA, WA, C, WD, GD, GK, Unknown	100%		5.0 (5–5)	1	No change	
Total Minutes Played at Injury	Total number of minutes played in game before injury	92%		5.0 (5–5)	1	No change	
Location on Court	Zones 1-9, Goal Circle, Unknown (See Diagram 1, in definitions)	85%		5.0 (5–5)	1	"Goal Circle" option added which will prompt completion of "Goal Circle – Location" if required	
If in Goal Circle – Location	Left Long, Mid Long, Right Long, Left Short, Mid Short, Right Short, Unknown (See Diagram 2)	77%	91%	5.0 (4–5)	1	No change. Location offers insight into player positioning and movement relative to the post and opponents. Injuries in different goal-circle zones reflect distinct actions and mechanics, helping identify situational trends and high-risk areas.	
Team Playing Phase at Time of Injury	Attack from centre pass, Attack following possession regain, Defence from centre pass, Defence following possession loss, Attack/Defence transition,	77%	91%	5.0 (4–5)	1	Retained. Identifies the tactical phase of play at the time of injury, providing context for player positioning, movement direction, and involvement in attacking or	

Variable	Category	Round 1 Agreement (%)	Round 2 Agreement (%)	Median (IQR)	Round Achieved Consensus	Summary Changes Round 1	Summary Changes Round 2
	Unknown					defensive actions	
Umpire Decision	Penalty against opponent, Penalty against player, No Penalty, Unknown	58%	83%	5.0 (4–5)	2	Retained with “Unknown” added. Although not essential for basic surveillance, “Umpire Decision” provides context on whether injurious contact was penalised, helping distinguish legal play from rule infringements and identify preventable mechanisms	
Any Further Descriptive Information	Any further descriptive Information (If the "Other (specify)" option was selected provide detail here)		100%	5.0 (5–5)	2	Added to capture any additional information	
Match Injuries (completed for all competitive match injuries)							
Match Information and Playing Situation (complete for all match injuries)							
Match Type	League Match, Cup Match, Friendly/Practice Match, Other (specify)	100%		5.0 (5–5)	1	Updated to reflect the types of competitive match play	
Match	Indoor, Outdoor	92%				Removed. “Match	

Variable	Category	Round 1 Agreement (%)	Round 2 Agreement (%)	Median (IQR)	Round Achieved Consensus	Summary Changes Round 1	Summary Changes Round 2
Environment						Environment" (Indoor/Outdoor) is redundant, as this information is captured in "Playing Surface."	
Playing Surface	Wooden sprung, Wooden non-sprung, Vinyl, Artificial turf, Rubber, Concrete, Grass, Asphalt tarmac, Other (specify), Unknown	92%		5.0 (5–5)	1	"Other (specify) added) no other change	
Player Status at Injury	Starting Player (continuous), Starting Player (re-entry), Substitute (entered from the bench), Unknown	58%	100%	5.0 (5–5)	2	"Starting Player or Substitution" changed to "Player Status at Injury." Categories added to distinguish continuous play, re-entry after rest, and substitution from the bench, providing clearer context for player readiness and exposure differences	
If a Substitution/Re-entry - Warm-up before Entry	Continuous activity, Targeted preparation, Rushed/Minimal preparation, None, Other (specify), Unknown		91%	5.0 (4–5)	2	Added to record warm-up type before substitution or re-entry (e.g., continuous, targeted, rushed, none), providing context on readiness and factors influencing injury risk.	Definitions updated: Timing guidance was added to capture the duration of substitution warm-ups, enabling clearer differentiation between brief on-court preparations

Variable	Category	Round 1 Agreement (%)	Round 2 Agreement (%)	Median (IQR)	Round Achieved Consensus	Summary Changes Round 1	Summary Changes Round 2
							and extended warm-up periods
Playing Position at Injury	GS, GA, WA, C, WD, GD, GK, Unknown	100%		5.0 (5–5)	1	"Unknown" added. No other changes	
Match Quarter	Quarter 1, Quarter 2, Quarter 3, Quarter 4, Extra Time, Other (specify), Unknown	85%		5.0 (5–5)	1	Added in "Extra Time" and "Other (specify)." No other changes.	
Total Minutes Played at Injury	Total number of minutes played in game before injury	92%		5.0 (5–5)	1	No change	
Time in Quarter	1-5 minutes, 6-10 minutes, 11-15 minutes	77%				Removed. This level of temporal detail was unnecessary, as broader variables (e.g., playing phase, match period) already capture game context.	
Location on Court	Zones 1-9, Goal Circle, Unknown (See Diagram 1, in definitions)	85%		5.0 (5–5)	1	"Goal Circle" option added which will prompt completion of "Goal Circle – Location" if required	
If in Goal Circle – Location	Left Long, Mid Long, Right Long, Left Short, Mid Short, Right Short, Unknown (See Diagram 2)	77%	91%	5.0 (4–5)	2	No change. Location offers insight into player positioning and movement relative to the post and opponents. Injuries in different goal-circle zones reflect distinct actions and mechanics, helping identify situational trends and high-risk areas	
Team Playing Phase at time of Injury	Attacking from centre pass, Attacking following possession regain, Defending from centre pass, Defending	77%	91%	5.0 (4–5)	2	Retained. Identifies the tactical phase of play at the time of injury, providing context for player positioning,	

Variable	Category	Round 1 Agreement (%)	Round 2 Agreement (%)	Median (IQR)	Round Achieved Consensus	Summary Changes Round 1	Summary Changes Round 2
	following possession loss, Attack/Defence transition, Unknown					movement direction, and involvement in attacking or defensive actions	
Player/Opponent behaviour (complete for all match injuries)							
Player Movement before Injury	Stationary, Bouncing, Walking, Shuffling, Jogging, Running, High-Speed Running, Sprinting, Change of Direction, Dodge, Pivot, Twist, Jump, Turn in Air, Landing, Roll, Other (specify), Unknown	92%		5.0 (5–5)	1	Added Other (specify). No other changes	
Movement Direction	Forwards, Forwards left diagonal, Forwards right diagonal, Lateral left, Lateral right, Backwards, Backwards left, Backwards right, Vertical, Rotation, Other (specify), Unclear	92%		5.0 (5–5)	1	Added Other (specify). No other changes	
Change in Movement Speed	Accelerating, Decelerating, Steady pace, N/A, Unclear	83%		5.0 (5–5)	1	Title changed from “Movement Velocity” to “Change in Movement Speed”	
If Jumping: Type	Two-footed take-off, Left foot take-off, Right foot take-off, Unclear	83%		5.0 (5–5)	1	No Change	
If Jumping: Relative Elevation	Minimal Elevation (feet just off ground), Moderate Elevation (noticeable lift typical of routine play), High Elevation (substantial elevation), Unclear	33%	91%	5.0 (4–5)	2	Renamed “Relative Elevation.” Categories revised to remove subjective terms (e.g., “close to maximum”) and rate height contextually by visible	

Variable	Category	Round 1 Agreement (%)	Round 2 Agreement (%)	Median (IQR)	Round Achieved Consensus	Summary Changes Round 1	Summary Changes Round 2
						elevation from the ground. Examples are provided in the “Instructions and Definitions”	
If Landing: Type	Double leg landing, Split landing, Single leg left, Single leg right, Unclear	83%		5.0 (5–5)	1	No Change	
If Landing: Balance	Balanced, Unbalanced, Unclear	85%		5.0 (5–5)	1	Clear definitions added in “Instructions and Definitions”	
If Landing: Footwork Violation	Yes, No, Unclear		92%	4.5 (4–5)	2	Added to record any footwork violation or irregularity at the time of injury, distinguishing biomechanical instability from technical or decision-making errors	
Playing Action at Injury	Shooting, Passing, Catching, Trying to get free, Marking, Off-ball Marking, Interception, Deflection, Block, Pick-up, Loose Ball, Throw-in, Defensive rebound, Attacking rebound, Other Specify, Unknown	91%		5.0 (5–5)	1	“Other (specify)” and “Unknown” added. No other changes	
Opponent Proximity to Injured Player	Within 90cm, Beyond 90cm	42%				Removed from tool. Contact type and nature provide more relevant information	
Contact: Timing and Type	No Contact, Contact before injury – Indirect, Contact at Injury – Direct, Contact at Injury – Indirect, Unclear	83%		5.0 (5–5)	1	“Contact” and “If Contact” have been combined into one category “Contact: Timing and Type” for clarity and efficiency	
If Contact: Nature of Contact	Collision with another player, Collision with umpire, Collision with ball, Collision with object (post/wall/floor),	92%		5.0 (5–5)	1	New Title: “Nature of Contact” “Other (specify) added	

Variable	Category	Round 1 Agreement (%)	Round 2 Agreement (%)	Median (IQR)	Round Achieved Consensus	Summary Changes Round 1	Summary Changes Round 2
	Opponent action (hold/push/bump/fall/arm fend), Other (specify), Unclear						
If Contact: Support Phase	Double-Leg Stance, Single-Leg Stance, Airborne, On the ground, Unclear		92%	5.0 (4–5)	2	Added to record body support position at contact, influencing balance, stability, and force absorption through the lower limbs	Category title changed from “If Contact: Stance” to “If Contact: Support Phase”
If Contact: Anticipation	Yes, No, Unclear		83%	4.5 (4–5)	2	Added to record whether contact was anticipated, reflecting behavioural and neuromuscular readiness that influences muscle activation, joint stiffness, and contact-related injury risk	
Umpire Decision	Penalty against opponent, Penalty against player, No Penalty, Unknown	58%	83%	5.0 (4–5)	2	Retained with “Unknown” added. Although not essential for basic surveillance, “Umpire Decision” provides context on whether injurious contact was penalised, helping distinguish legal play from rule infringements and identify preventable mechanisms	
Any Further Descriptive Information	Any further descriptive Information (If the "Other (specify)" option was selected provide detail here)	100%		5.0 (5–5)	1	Updated description	

Appendix D

Supplementary materials for Study 4: Pilot Evaluation of the Biomechanical Domain of the Netball Injury Inciting Event Classification System (Chapter 6)

Table D1 *Summary of expert ratings for the preliminary biomechanical descriptors of the NIIECS biomechanical domain*

Variable	Category	n	Range	Median (IQR)
Whole body and joint/tissue biomechanics	**Body alignment at probable injury event** (Index Frame – IF)	5	2–5	4 (3–5)
Head/Neck	**Sagittal Plane**: Flexion, Extension or Neutral.	11	3–5	5 (4–5)
	Frontal Plane: Abduction, Adduction or Neutral.	11	3–5	5 (4–5)
	Transverse Plane: External rotation, Internal rotation, or Neutral rotation	11	3–5	5 (4–5)
Shoulder	**Sagittal Plane**: Flexion, Extension or Neutral.	11	3–5	5 (4–5)
	Frontal Plane: Abduction, Adduction or Neutral.	11	3–5	5 (4–5)
	Transverse Plane: External rotation, Internal rotation or Neutral, Horizontal Abduction, Horizontal Adduction or Neutral	11	3–5	5 (4–5)
Elbow	**Sagittal Plane**: Flexion, Extension or Neutral	11	2–5	5 (4–5)
	Frontal Plane: Varus, Valgus or Neutral	11	2–5	5 (3–5)
Forearm	**Transverse plane**: Pronation (palm down), Supination (palm up) or neutral	11	3–5	5 (4–5)
Hand/Wrist	**Sagittal Plane**: Flexion, Extension or Neutral	11	3–5	5 (4–5)
	Frontal Plane: Radial Deviation, Ulnar Deviation or Neutral	11	3–5	5 (4–5)
Trunk	**Sagittal Plane**: Flexion, Extension or Neutral	11	3–5	5 (4–5)
	Frontal Plane: Lateral flexion toward injured side, Lateral flexion away from injured side or Neutral	11	3–5	5 (4–5)
	Transverse Plane: Rotation toward injury, Rotation away from injury or Neutral	11	3–5	5 (4–5
Hip	**Sagittal Plane**: Flexion, Extension or Neutral	11	3–5	5 (4–5)
	Frontal Plane: Abduction, Adduction or Neutral	11	3–5	5 (4–5)

	Transverse Plane: External rotation, Internal rotation or Neutral	11	3–5	5 (4–5)
Knee	**Sagittal Plane**: Flexion, Extension or Neutral	11	3–5	5 (4–5)
	Frontal Plane: Abduction, Adduction or Neutral	11	3–5	5 (4–5)
	Transverse Plane: External rotation, Internal rotation or Neutral	11	3–5	5 (4–5)
Ankle/Foot	**Sagittal Plane**: Dorsiflexion, Plantarflexion or Neutral	11	3–5	5 (4–5)
	Frontal Plane: Inversion, Eversion or Neutral	11	3–5	5 (4–5)
	Transverse Plane: Supination, Pronation or Neutral	11	3–5	5 (4–5)
	Initial ground contact: Hindfoot, Midfoot, Forefoot or Combination	11	3–5	5 (4–5)
	Position relative to vertical: In line, In-front, Behind	11	3–5	5 (4–5)
Additional Information		11	3–5	5 (4–5)

Appendix E

Applied consultancy reports for England Netball arising from the Vitality Netball Superleague injury epidemiology programme

Vitality Netball Superleague 2019 Injury Surveillance Report

SUBMITTED TO ENGLAND NETBALL ON 20/9/19

Sara Horne, Laura Hills, and Bill Baltzopoulos
Sport, Health and Exercise Sciences, College of Health and Life Sciences
BRUNEL UNIVERSITY LONDON

Executive Summary

1.1 In October 2018 England Netball gave their consent to collaborate in a PhD research project to identify the risk factors and mechanisms of injury in elite netball. As the premier competition in the UK it was agreed the research could be conducted on the Vitality Netball Superleague (VNSL).

1.2 This research aims to redress the injury knowledge gap in netball at the elite level and provide the crucial evidence to inform the development of effective prevention strategies. The first step in this process is to provide accurate and reliable injury surveillance data to identify the true injury problems in the sport.

1.3 To fulfil this aim the existing VNSL injury audit was developed to include current research directives. In particular the relationship between injuries (whether the injury is a new or recurring “subsequent” injury) and a focus on measuring overuse injuries was incorporated to provide a more complete picture of the injury problem. To facilitate this a broader definition of injuries was used to include all injuries requiring medical attention, including time-loss injuries and the more transient and overuse injuries without time-loss.

1.4 A detailed assessment of the injuries occurring in the 2019 VNSL was conducted with injuries recorded by the team physiotherapists using the newly developed, online injury surveillance system. Initially 7 teams agreed to take part in the study with 4 teams recording injury data by the end of the competition.

1.5 The main findings from the injury surveillance conducted on the 2019 VNSL competition in this report were:

- 64 injuries were recorded in 53 players from 4 teams equating to 5.15 injuries per 1000 playing and training hours exposure.
- 30 injuries were recorded in matches equating to 5.99 injuries per 1000 playing hours and 34 injuries recorded in training equating to 4.58 injuries per 1000 training hours.
- 31 of the 53 players (58%) sustained at least 1 injury. 21 player’s sustained more than 1 injury (subsequent injury). The subsequent injuries were mostly new injuries occurring at a different injury site but 25% were recurrent exacerbations where the initial index injury had not healed.
- The majority of match injuries were acute with an even distribution of acute and overuse activities occurring during training activities.

- The highest frequency of match injuries occurred in March with most training injuries in January and February. Overall the first 2 months recorded the highest injury frequency.
- The C, GS and GK positions recorded the highest injury frequency with relatively equal numbers recorded during matches and training. The least injured position was GD.
- Most injuries were recorded in the 4th quarter of matches with 5-10 minutes in this quarter the most frequent time for injury occurrence.
- 45% of the 64 injuries were to the lower extremity. The most frequently injured sites were the back, knee and ankle. Overuse muscle/tendon injuries were most common in the back, with an equal frequency of overuse muscle/tendon, acute sprains and bruise contusions in addition to 1 ACL rupture occurring at the knee. Ankle injuries were mostly acute sprains.
- The most severe injuries were at the knee resulting in the most time-loss from netball by a large margin. Ankle injuries were the next highest cause of time-loss from the sport. Non time-loss back injuries resulted in the highest accumulative pain scores with non-time loss knee injuries causing the second highest accumulative pain scores.
- The most frequent events causing non-contact injuries was running and being struck by a player was the most frequent cause of contact injuries. Variations in the cause of injury was seen across injury sites. Knee and ankle injuries resulted from a wide range of events including landing from a jump, changes of direction, running, collisions and being struck by a player.
- 67% of players sustaining knee injuries reported wearing ankle tape or braces and 51% of players with ankle injuries.

1.6 The findings from the 2019 VNSL injury surveillance have identified some initial evidence of the injury problems in 4 teams revealing some similarities and differences to previous, recent injury audits in the competition.

1.7 Further injury assessment is required in subsequent seasons using consistent methodologies and data across all 10 VNSL teams to capture the true injury issues in the competition and develop the evidence base.

1.8 To facilitate the collection of accurate injury data from more teams in the VNSL, training will be conducted at the VNSL Forum on 13th November 2019, fully explaining the injury surveillance system and how to record the team injury data.

Background

2.1 Sports participation carries a high risk of injury with considerable negative effects to individuals, their team, public health and the economy. To date attempts to reduce sports injuries through prevention strategies have been limited as a result of non-optimal methods of injury surveillance and little research identifying the causes of injuries. Hence many preventive strategies have been based on a lack of essential evidence as to why an athlete is at risk and how the injuries occur. Understanding these factors is critical to inform the development of evidence-based prevention programmes and reduce the sports injury burden.

2.2 To develop the evidence to inform effective prevention strategies a structured approach is recommended[1]. First injury surveillance studies are required to identify the magnitude of the sports injury problem before the injury risk factors and causes are identified. This subsequently informs the development of appropriate injury prevention strategies with the final step assessing the effectiveness of the strategies. However, in many sports the initial step, assessing the injury problems, suffers from inconsistent and inaccurate methods making it difficult to ascertain the true injury issues. Injury research over the last 15 years has focused on identifying the methods to ensure injury surveillance studies produce consistent, high quality data. These methods now require implementation across sports to start to identify the crucial data for the injury evidence base.

2.3 Netball is a sport with an increasing profile and participation base, but it also has a reputation for a high risk of injury particularly to the lower limb. Indeed, research has consistently reported the ankle and knee to be the most common sites of injury[2-6] with debilitating ACL injuries a growing cause for concern in the sport[7]. However, currently little research has been conducted in netball to try to understand why and how injuries occur. Thus, further work is required to address this knowledge gap and provide the detailed pathway to the prevention of injuries. The starting point is to provide accurate, valid and contemporary injury surveillance data in Netball.

2.4 The Vitality Netball Superleague (VNSL) is the UK's top-level competition involving 10 teams from England, Wales and Scotland comprising elite and international players from the UK and across the world. The competition includes 18 rounds, semi-finals and finals totaling 94 matches, usually running from February to June. The previous injury surveillance conducted on the VNSL was developed from the Rugby Union consensus statement[8] published in 2007. However, recent research directives outline the importance of identifying the relationship between injuries. Across a season, athletes may sustain no injuries, one, or more than one related or unrelated injuries hence, whether the injury is a new, “index” injury or a subsequent injury is an important consideration. Correctly defining and recording subsequent injuries is critical for the calculation of accurate injury incidence rates and consequently the identification of the risk factors and mechanisms of such injuries. No known injury surveillance conducted in Netball has differentiated types of subsequent injuries thus far. Furthermore, as in many team sports, there has been limited focus on overuse injuries occurring in Netball. Thus, little is known of the magnitude of overuse injuries in the sport. These recent methodological recommendations are essential to ensure the true injury issues in Netball are accurately identified.

2.5 In October 2018 England Netball agreed to collaborate in a PhD research project which aims to redress the injury knowledge gap and identify the risk factors and mechanisms of injury in elite netball. The first step of this PhD research was to develop the existing VNSL injury surveillance system, based on up-to-date research directives, and subsequently implement the new system in the 2019 VNSL competition. The following report presents the findings from the injury surveillance conducted during the VNSL 2019.

Methodology

3.1 A prospective cohort design was used to assess the incidence and characteristics of injuries during the 2019 VNSL competition.

3.2 England Netball provided written consent to conduct the research in the VNSL competition and ethical approval to conduct the research was gained from the College of Health and Life Sciences Research Ethics Committee at Brunel University. Following this the research was presented at the VNSL Forum in November 2018 to the team coaches and support staff and England Netball performance staff. Gatekeeper written consent from each VNSL team to take part in the injury surveillance study was sought after the presentation. Following team agreement each team physiotherapist facilitated the collection of each individual player’s written informed consent prior to the start of the competition. On receipt of the consent forms a unique ID code was allocated to each player to ensure anonymity and confidentiality of all individual data.

3.3 The injury surveillance system was developed prior to the start of the VNSL 2019 competition on January 5th, 2019. This involved modifying the existing injury audit based on current methodological guidelines in the sports injury literature. Three injury report forms were developed a) Player Baseline Information Form to record player anthropometrics and previous injury history, b) Player Exposure Form to record training and match exposure for the calculation of injury incidence rates and c) Player Injury Report Form to record the injuries and their associated factors during the competition. The injury report forms are presented in the Appendices.

3.4 In developing the injury surveillance forms injury definitions for the sport, competition and requirements of the research were clearly identified. A reportable injury was defined as one that occurs as a result of training or match-play in the VNSL 2019 and which led to one of the following consequences: 1) Medical attention or advice (from team physiotherapist and/or other medical professional), 2) Time-Loss (a reduction in the amount or level of netball activity). This more inclusive definition was selected to include minor, transient injuries and overuse injuries not resulting in time-loss to gain a more complete picture of the full range of injuries in the competition.

3.5 To record the relationship between injuries this study adopted the subsequent injury classification system of Hamilton et al. (2011)[9]. Hence, all injuries were classified as either a First "Index" Injury (The first injury that occurred during the VNSL competition), or a Subsequent Injury (any injury occurring after the first index injury). Subsequent injuries were further classified as 1) Subsequent New Injuries (completely different location to Index Injury), 2) Local Injury (same location but different type to Index Injury), 3) Recurrent Injury (Exacerbation) (same site and type as index injury but Index injury not fully healed at time of recurrence) or Recurrent Injury (Re-injury) (same site and type as index injury, Index injury fully healed at time of recurrence). If more than one injury occurred in a single event this was recorded as a multiple injury.

3.6 The mode of injury was classified as acute or overuse with acute injuries defined as those resulting from a specific, identifiable traumatic event and overuse injuries as those caused by repeated micro-trauma without a single, identifiable event.

3.7 Injury severity was recorded according to whether the injury resulted in any time-lost from participation. Hence the severity of all time-loss injuries was recorded as the total number of days lost from training and matches. The severity of overuse injuries resulting in no time-loss were defined according to the athlete's functional capacity and pain levels. The Numeric Rating Scale for Pain (NRS) was adopted to rate a player's level of pain using an 11-point numeric scale[10].

3.8 All severity ratings and subsequent injuries were determined according to the definition of a fully healed injury being one in which the athlete had returned to full participation and/or was no longer receiving medical treatment or was no longer experiencing pain symptoms[9,11]. As the most widely used injury classification system, the Orchard Sports Injury Classification System (OSICS)[12] was used to provide the specific injury diagnosis.

3.9 The full set of injury definitions were provided with the Injury Report Form as a permanent reference for the injury data recorders (team physiotherapists) to facilitate consistency and accuracy of data recording (See Appendices). The forms were additionally designed for ease of recording and to minimise the data recorder workload.

3.10 Following agreement from England Netball the injury report forms were uploaded to an online platform allowing access through computers, tablets or smartphones. The online injury surveillance system allowed ease of access and recording, plus the protection of individual player data.

3.11 Full instructions were forwarded to the team physiotherapists via email to explain the forms and direct them to the form instructions and injury definitions. A follow up telephone conversation was provided where required to further explain the data recording requirements. Each physiotherapist subsequently diagnosed, treated and recorded the participant’s baseline data, exposure data and any training and match injuries when presented to them on the relevant forms, using the unique player ID codes. The physiotherapists were encouraged to record their teams' injuries no longer than a week after each game to avoid recall bias. Regular contact was maintained with the physiotherapists to answer questions and provide motivation to ensure compliance with the study. Furthermore, a mid-competition injury summary report was forwarded to each team to encourage engagement with the study.

3.12 On completion of the 2019 VNSL competition the injury data were analysed to identify an overall injury incidence rate and separate incidence rates for training and match injuries. The total number of injuries equalled the number of first Index injuries plus the number of new subsequent injuries. The different types of subsequent injury (local injury, recurrent (exacerbation), recurrent (re-injury) were counted as part of the unresolved index injury. Injury incidence rates were calculated by dividing the total number of injuries by the exposure hours and multiplying by 1000 to obtain the injury incidence per 1000 hours. For matches this equated to 1000 playing hours and for training 1000 training hours. The exposure values were combined to calculate the overall competition injury incidence rate per 1000 hours. The method of calculating the incidence rates is described in King et al., (2009)[13].

3.13 Descriptive analysis of injuries according to overall player injury frequency, subsequent injury frequency, injury activity and mode, month of injury, injury position, time of injury in the match, injury site and injury severity and cause (mechanism) was conducted. Data are presented as the total percentage injuries or number of injuries across all teams and as percentage match and training and acute an overuse injuries where appropriate. Differences in the range of team values only are identified to ensure individual player data protection.

Results

4.1 Baseline Data

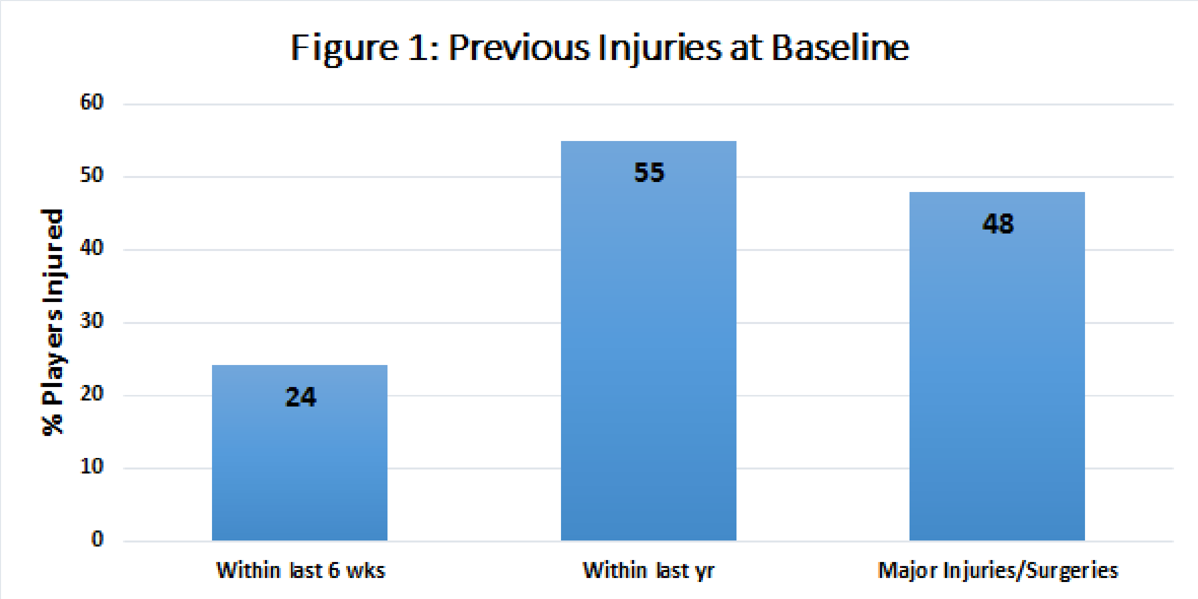
4.1.1 Baseline data (prior to the start of the competition) was obtained from 42 out of 53 players. Their mean age, height and weight was 25 years, 179.5 cm and 74 kg. 86% of players reported the right side to be there dominant throwing side. Ankle protection, in the form of tape or braces, was worn by 71% of players while 29% wore no ankle protection. 40% of players wore ankle tape for both training and matches with 12% wearing tape for matches only and 19% wearing ankle braces only. Variation in ankle taping/bracing practices was demonstrated across teams.

4.2.2 At baseline, injuries occurring in the previous 6 weeks and 1-year period were reported in addition to any major injuries or surgeries which resulted in more than 6 weeks out of the sport. Figure 1 presents the percentage number of players with previous injuries. Again, considerable variation in previous injury history was reported across teams particularly in the 6 weeks prior to the start of the season with players injured ranging from 0 to 50% of the full squad.

4.2 Exposure Data

4.2.1 For the 4 teams who take part in the study a total of 1.5 exposure hours per match (match + warm-up hours) equated to a total of 5008.5 playing exposure hours.

4.2.2 The 4 teams training exposure hours were calculated from the exposure data reported by the team physiotherapists. The average training hours were recorded as 7 per week and number of sessions as 5 per week over the competition period. The total training hours equated to 7420 hours of training exposure.



4.2.3 The overall exposure hours over the 2019 VNSL competition for the 4 teams equated to 12 4285.5 playing and training exposure hours.

4.2 Injury Incidence Rates

4.2.1 At the start of the 2019 VNSL competition 7 teams provided their agreement to take part in the injury surveillance. By the end of the competition individual player consent forms from 6 teams had been received but data from only 4 out of 10 teams were recorded on the online surveillance system. Thus, a total of 53 player's injury data from 4 teams was reported. This means the findings from this injury surveillance represent a snapshot of the injury issues in the VNSL 2019 competition.

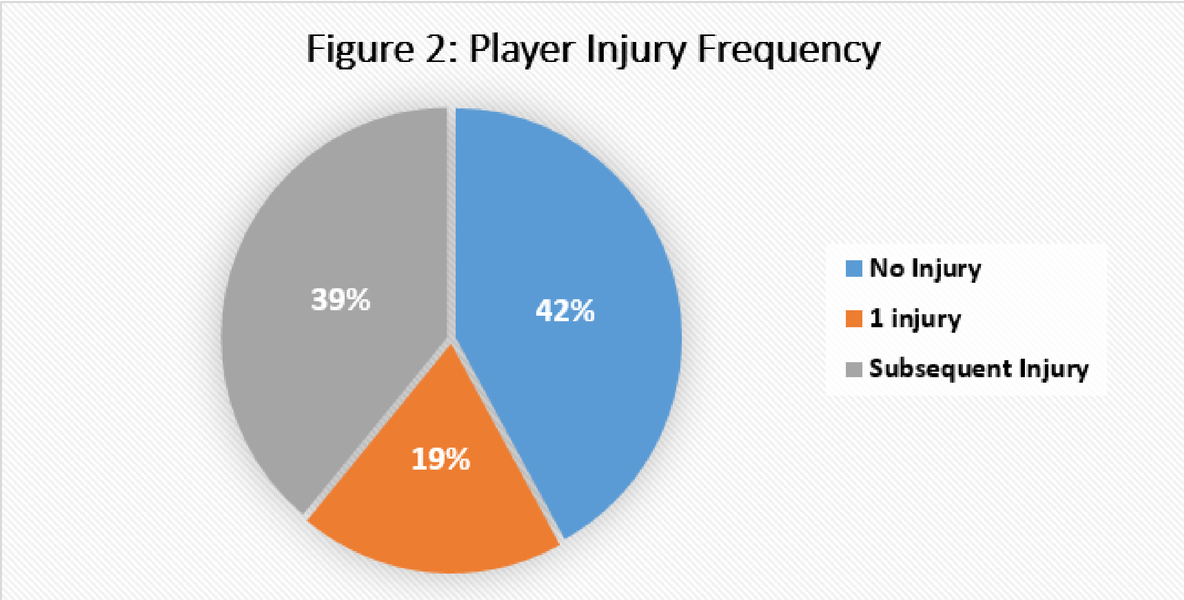
4.2.2 A total of 64 injuries were reported which is equivalent to 5.15 injuries per 1000 hours of VNSL 2019 exposure. 30 (47%) of these injuries occurred in VNSL matches which represents an incidence rate of 5.99 injuries per 1000 hours playing exposure. 34 injuries (53%) occurred during VNSL training activities; an incidence rate of 4.58 injuries per 1000 training hours.

4.2.3 The 64 injuries reported in the VNSL 2019 is similar to the 59 injuries reported in 2016 VNSL season but higher than the 29 recorded over the 2018 season. A slightly lower incidence rate is reported in the 2019 injury surveillance compared to the rate of 9.08 injuries per 1000 hours of exposure reported in the 2016 VNSL season.

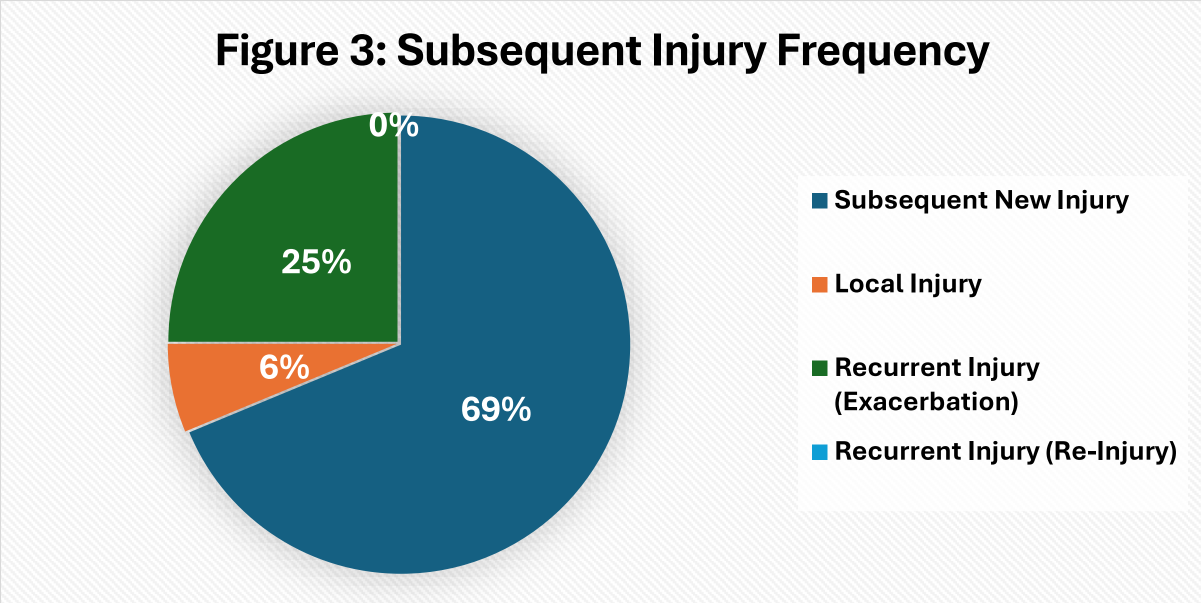
4.2.4 Considerable variation was seen in the number of injuries recorded across teams.

4.3 Injury Surveillance Data

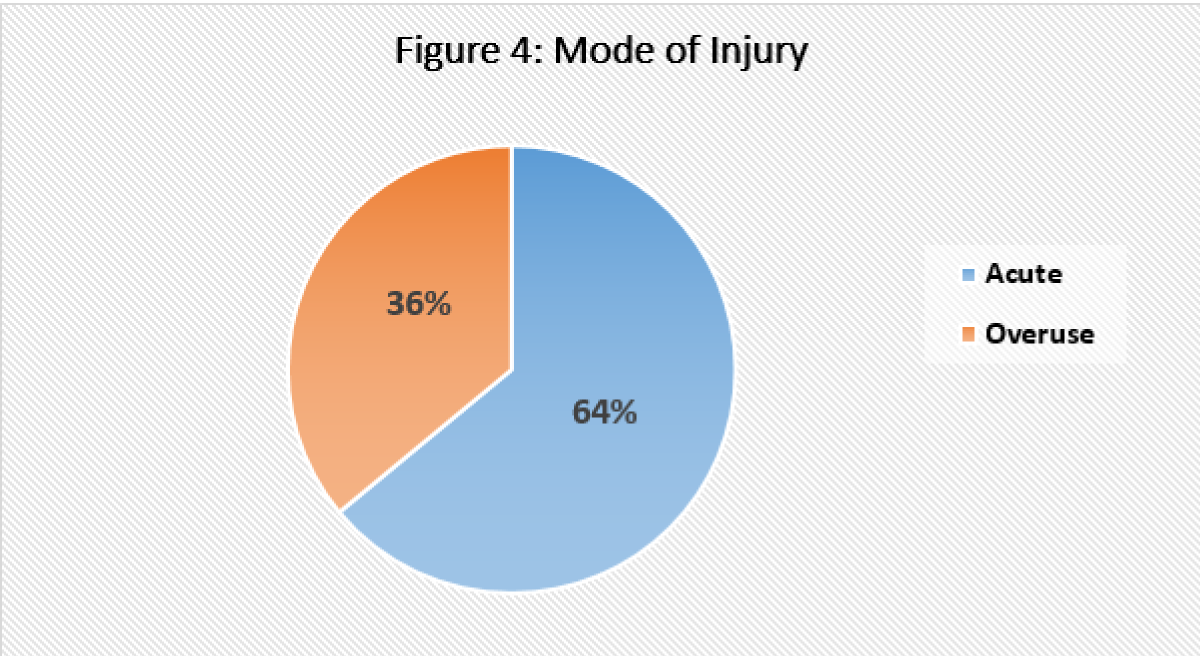
4.3.1 The 64 injuries reported in 4 teams during the 2019 VNSL competition were sustained by 31 (58%) of players. Figure 2 shows the percentage player injury frequency sustained by the 53 players participating in the injury surveillance. No injuries were reported in 42% (n=22) of the players. Of the 58% who sustained injuries, 19% (n=10) had 1 injury with 39% (n=21) sustaining some form of subsequent injury (subsequent new injury, local injury, recurrent (exacerbation) or recurrent (re-injury)) after their first index injury. Across the 4 teams the players in each squad that sustained at least 1 injury ranged from 45% to 67%.



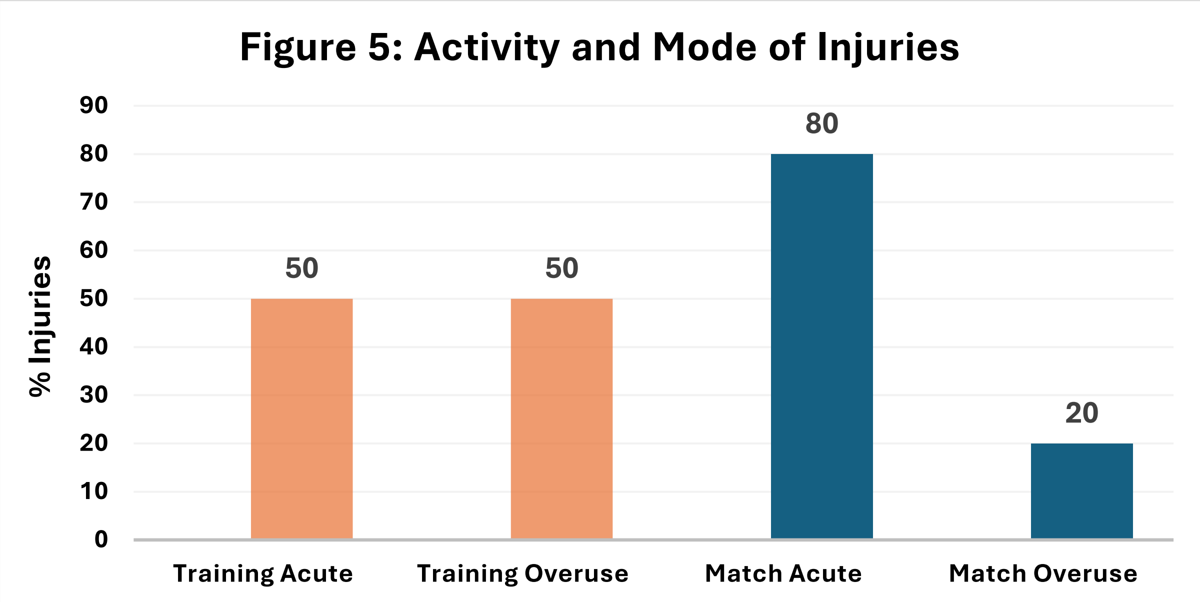
4.3.2 Figure 3 shows the frequency of different types of subsequent injuries across the 2019 VNSL season. 21 (68%) of the 31 players injured suffered a total of 48 subsequent injuries. The majority of these subsequent injuries (69%, n= 33) were a subsequent new injury, occurring in a completely different location to their first index injury. 6% (n=3) of players suffered a local injury (same location but different type to Index Injury) and 25% (n=12) a recurrent injury (exacerbation) where an index injury that had not fully healed recurred. No players experienced a recurrent injury (re-injury) where an initial index injury that had fully healed recurred. In 4 players the initial index injury recurred as an exacerbation on 2 occasions. Hence, a total of 12 exacerbations resulted from 8 injuries. Across the 4 teams differences in the types and number of subsequent injuries were observed with no recurrent exacerbations reported in 1 team compared to 9 in another team and no local injuries in 2 teams compared to 2 in another team.



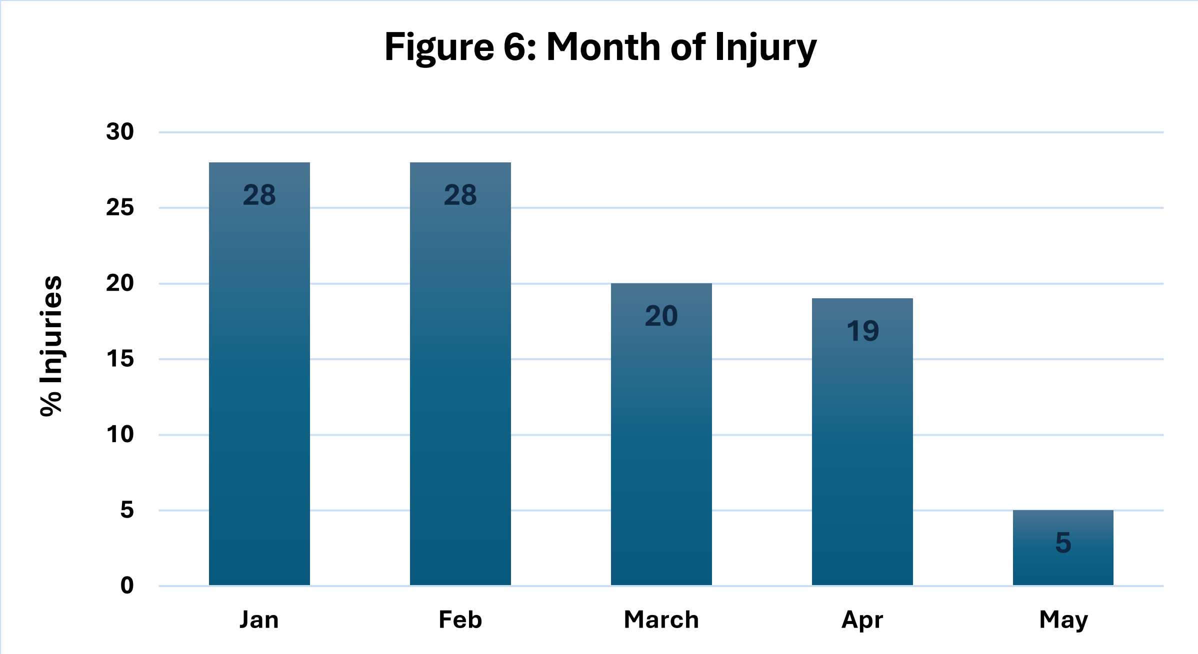
4.3.3 The mode of injury presented in Figure 4 shows that a higher percentage of injuries were acute (64%, n=41) compared to overuse (36%, n=23) in nature. 41% (n=17) of the acute injuries resulted from some form of contact with another player or object such as the post, floor, wall or the ball, with 59% (n=24) resulting from non-contact causes. The 23 overuse injuries by comparison were all a consequence of non-contact events. The acute and overuse non-contact injuries were typically reported to be caused by running, changes of direction or overuse. All teams recorded a higher percentage of acute compared to overuse injuries with acute injuries ranging from 56% to 75% and overuse injuries 25% to 44% of the total team injuries.



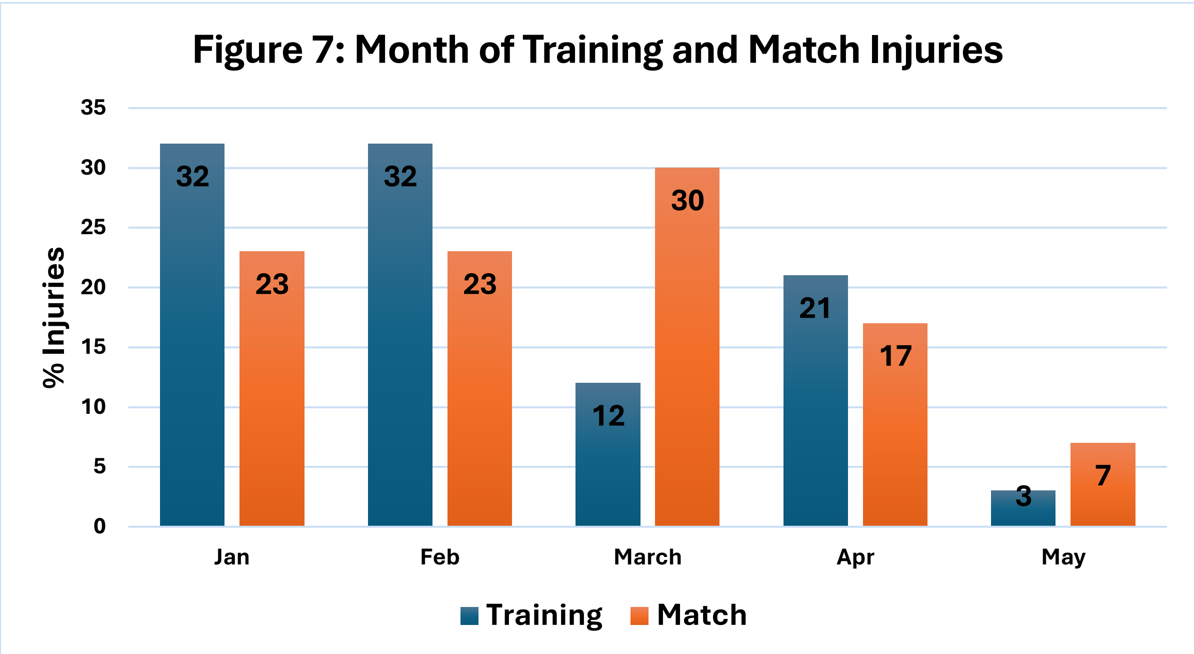
4.3.4 Figure 5 shows the percentage injuries for activity and mode combined. Of the 34 total training injuries sustained during the 2019 season an even distribution of acute and overuse injuries (50%, n=17) occurred during the various training activities including weight training, conditioning, on court technical training and training matches. However, most of the 30 match injuries were acute injuries (80%, n=24), with just 20% (n=6) resulting from overuse. A similar pattern of acute and overuse injuries ocurring during training sessions and matches were reported across all teams. Furthermore 80% of injuries that resulted in an recurrent exacerbation or local injury were recorded as overuse injuries occurring during training activities.



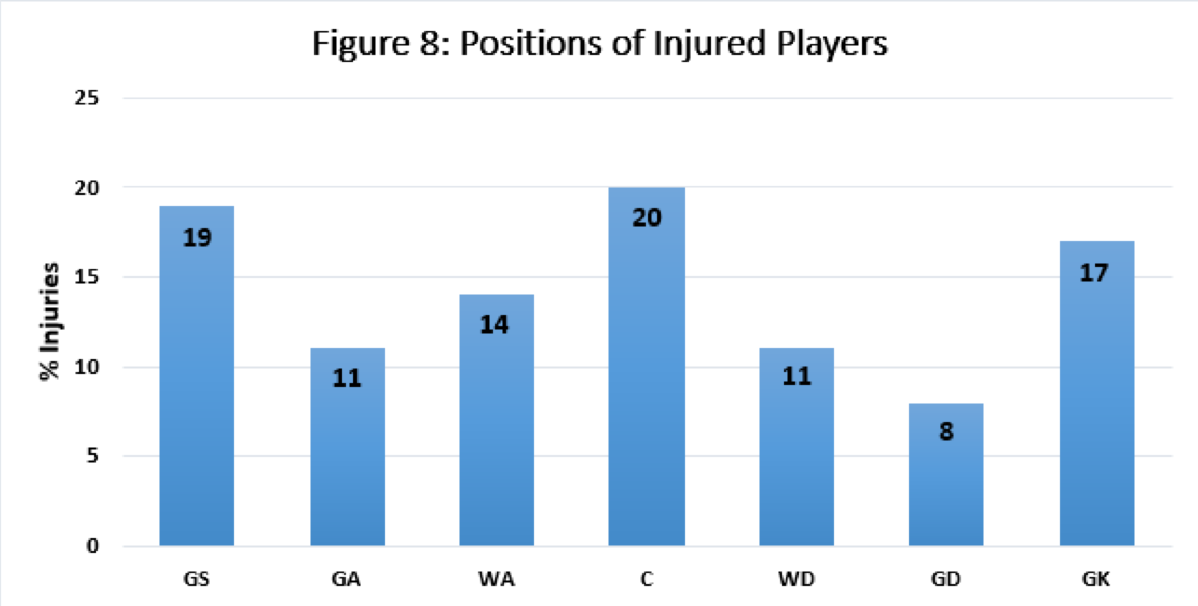
4.3.5 The monthly distribution of injuries across the 5-month season is presented in Figure 6. The highest percentage of injuries occurred within the first 2 months of the season with over half (56%, n=36) of all injuries in these months. This is despite the lower number of matches in these 2 months (January = 10 matches, February = 13 matches). A greater number of matches took place in March (n=15) and April (n=17) but the number of injuries decreased in these months to 20% (n=13) and 19% (n=12) respectively. With the season ending on 18th May and only 8 matches in the month the lowest injury frequency (5%, n=3) was observed in May. A similar pattern of injuries across the 5 months was seen in the 4 VNSL teams. In most cases Injuries that resulted in an exacerbation or local injury occurred within 1 month of the initial index injury.



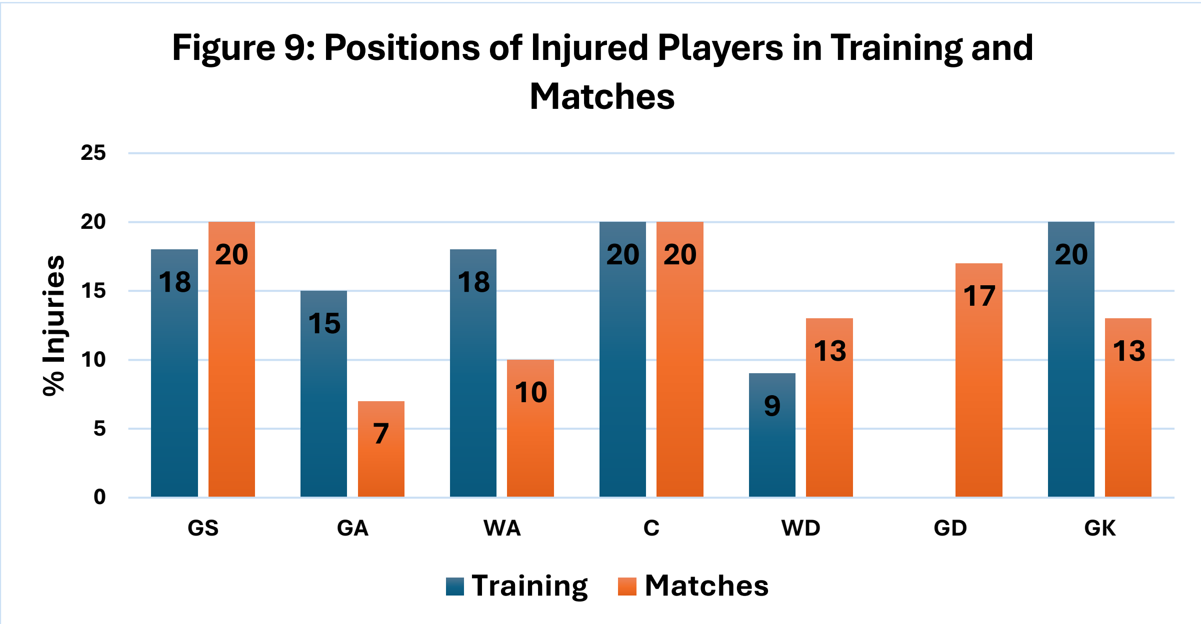
4.3.5 When separated into training and match injuries the distribution of injuries across the 5 months differed (Figure 7). Most of the 34 training injuries occurred in January and February (64%, n=22) although an increase was also seen in April (21%, n=7). In comparison the highest number of match injuries were sustained in March (30%, n= 9), with 23% (n=7) reported in both January and February. Slight variations in these injury patterns per month across teams were present.



4.3.6 Figure 8 displays the distribution of injuries across the 7 netball playing positions. Most injuries in the 2019 competition occurred in the C (20%, n=13), GS (19%, n=12) and GK (17%, n=11) positions with the lowest injuries in the GD (8%, n=5) position. Relatively similar injury findings were reported across the positions in the 4 VNSL teams.

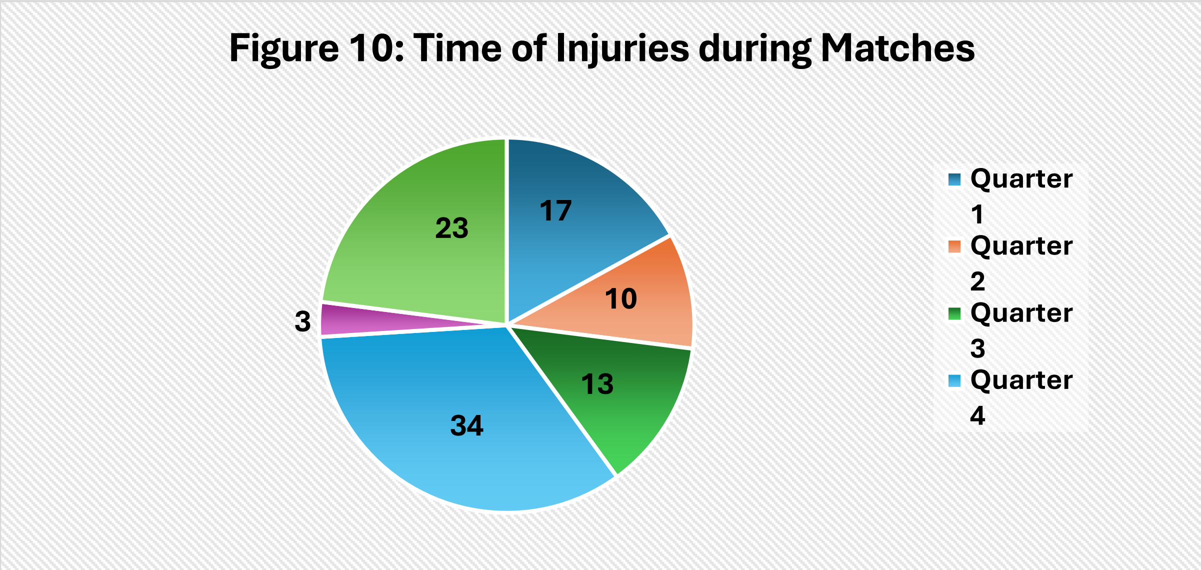


4.3.7 The position of injured players during training and matches, shown in Figure 9, reveals a consistently high injury percentage in the C and GS positions (C: 20%, n=7 in training, n=6 in matches, GS: 18%, n=6 in training and 20%, n=6 in matches). Players in the GA, WA and GK positions sustained a higher percentage of injuries in training compared to matches. Conversely, the WD position suffered more injuries when playing matches in comparison to training as did those playing GD whose 5 injuries (17%) all occurred during matches.

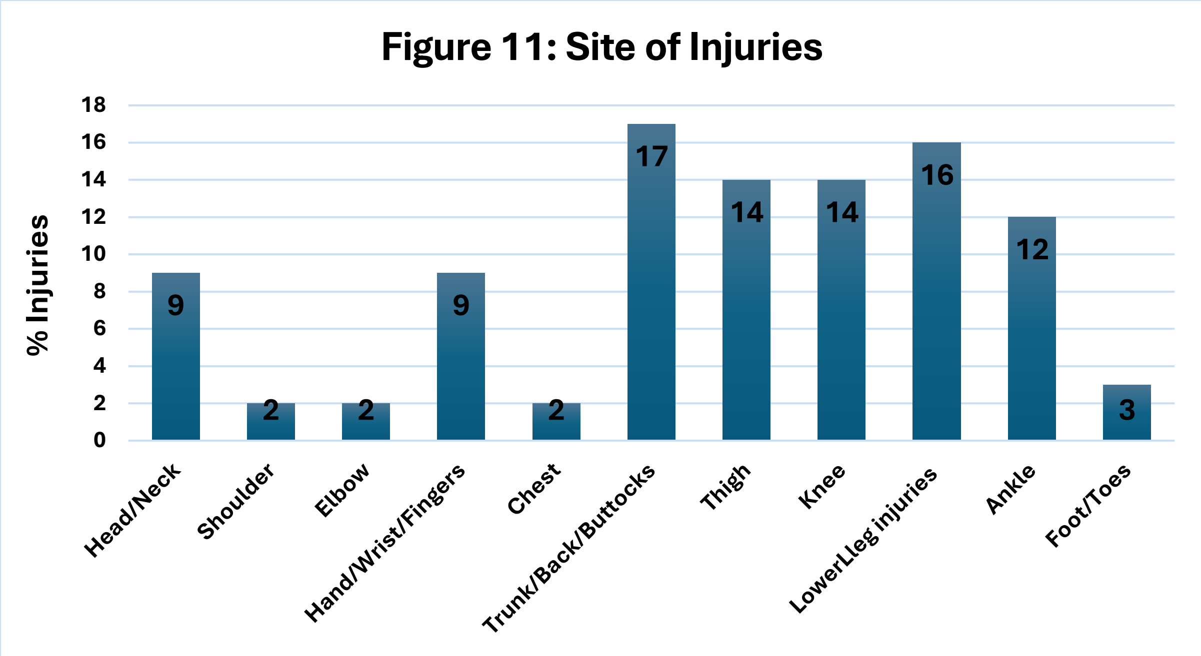


4.3.8 Figure 10 shows most match injuries occurred within the 4th quarter of the game

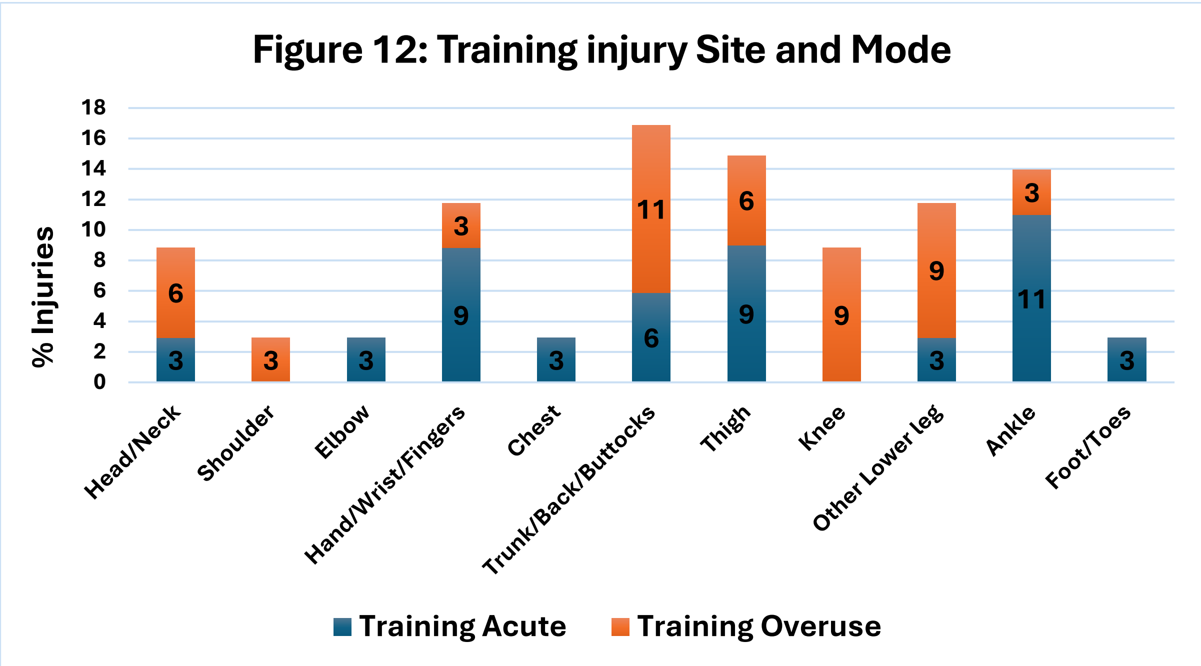
(34%, n=10). However, the time of injury was unknown in 23% (n=7) of injury cases. 50% (n=5) of the 4th quarter injuries occurred in minutes 5-10 of the quarter with 30% (n=3) in minutes 10-15. A higher percentage of injuries in the 4th quarter was consistent for the majority of teams although one team had their highest number of injuries in quarter 1.

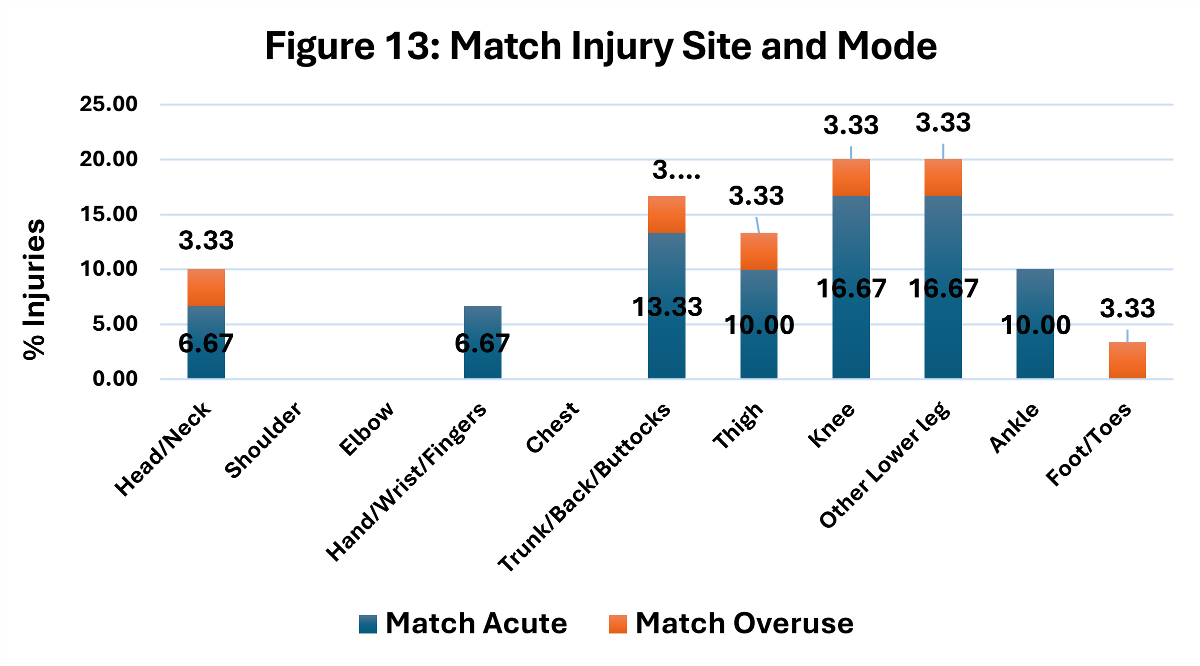


4.3.9 The site of injuries in the VNSL 2019 are presented in Figure 11. Of the 64 injuries across the 4 teams most 45% (n=29) were located at the lower extremities (knee, lower leg, ankle and foot/toes). Lower leg (16%, n=10), knee (14%, n=9) and ankle (12%, n=8) injuries were the most frequent lower extremity injuries. 70% (n=7) of the lower leg injuries were acute calf strains, with overuse muscle/tendon injuries to the Achilles tendon and shin forming the remaining injuries. Knee injuries (n=4) consisted of overuse muscle tendon injuries with 2 sprains, 2 bruise/contusions and 1 rupture of the ACL ligament. The most common type of ankle injury was an acute sprain (n=6). However, the body region most frequently injured was the trunk/back/buttocks (17%, n=11). The majority of these injuries were to the back which accounted for 9 injuries (82%), with overuse muscle tendon injuries (n=5), strains (n=3) and sprains (n=1) the diagnosed types of injury. 14% (n=9) of injuries were also recorded at the thigh, these included 4 hamstring injuries (2 overuse muscle tendon, 2 strains), and 4 quadriceps injuries (2 bruise/contusions, 1 overuse muscle tendon and 1 strain). Injuries to the head/neck were mainly overuse muscle tendon or sprain injuries and the hand/wrist/finger injuries were mostly cuts/lacerations. No injuries were recorded at the arm or hip/groin.



4.3.10. The percentage overuse and acute injuries at each injury site sustained during training activities (Figure 12) and matches (Figure 13) show acute injuries are most common during matches for most injury sites. However, the overuse and acute injuries are more evenly distributed during training activities across most injury sites with the exception of knee injuries which were predominantly acute during matches (16.67%, n=5) and all overuse injuries during training (9%, n=3).



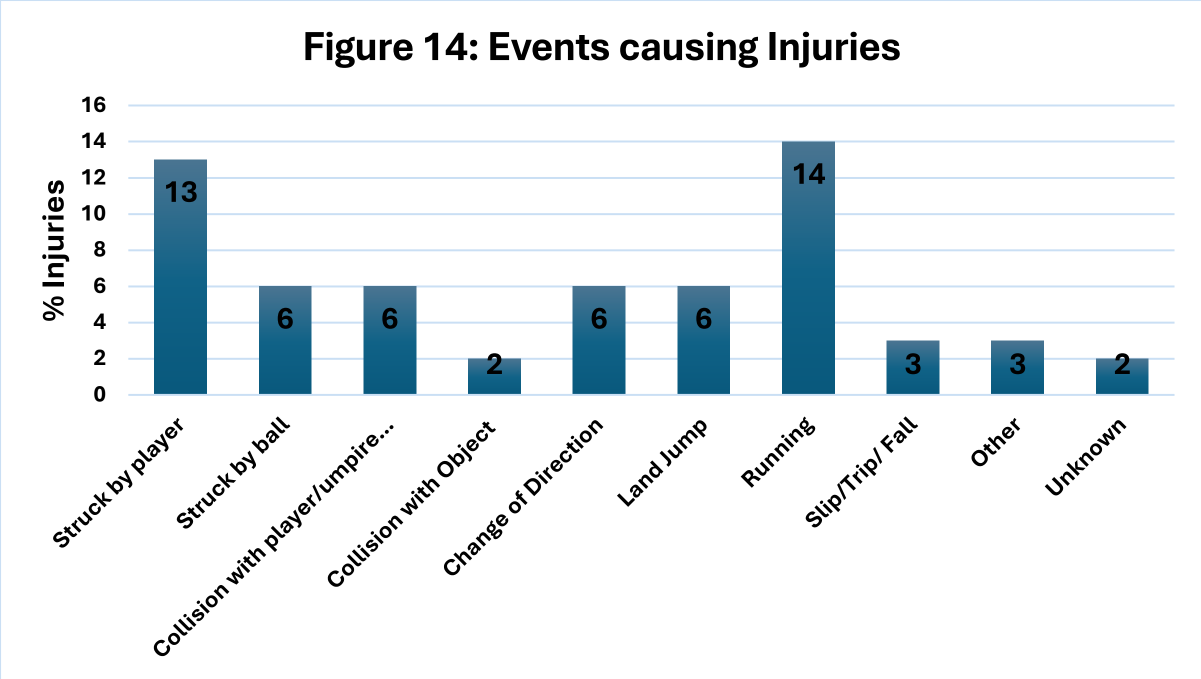


4.3.11 The following table shows the severity of injuries in relation to the site of injury (Table 1). The severity of all time-loss injuries was recorded as the total number of days lost from training and competing in the VNSL. Most time-loss injuries (46%, n= 26) across all sites resulted in 0 days absence from playing. 14 injuries (22%) largely in the lower extremities, thigh and trunk/back/buttocks led to a period of time loss from training or competing in the VNSL. The most severe time-loss injuries were at the knee which led to a total of at least 231 days lost from 2 injuries. One knee sprain resulted in 48 days absence and an ACL rupture was a season ending injury. The exact number of days lost to this injury is as yet unknown thus it was recorded as a long-term injury with a minimum of 6 months days lost. 3 ankle injuries, 3 thigh injuries and 1 hand/wrist/finger injury also led to a considerable number of days out of the sport (ankle: 35 days, thigh: 26 days, hand/wrist/fingers: 26 days). The severity of non-time-loss overuse injuries were recorded according to the NRS pain score with 0 representing no pain and 10 the worst imaginable pain. Only 2 injuries at the elbow and chest recorded no pain with most overuse injuries reported levels of pain ranging from 8 to 2. The highest pain ratings over a total of 5 overuse injuries were recorded in the trunk/back/buttocks. The highest pain rating of 8 was recorded in this category with the remaining injuries ranging from pain levels of 6 to 2. Overuse Injuries sustained at the lower extremity (knee, lower leg, ankle and foot/toes) also resulted in a high number of injuries generating higher levels of pain. The knee rated most highly in the lower extremity for pain with 2 injuries rating a 5 and 2 further injuries rating pain levels of 4 and 3. At the ankle 1 injury rated a pain level 7 and across 4 lower leg injuries the ratings ranged from 6 to 3.

Table 1: Injury site by severity of injuries

	Time-Loss Injuries			Non Time-Loss Overuse Injuries	
Injury Site	**Number Injuries 0 days Time-Loss**	**Number Injuries 1 day ->6 months Time Loss**	**Total days lost**	**Number Non Time-Loss Overuse Injuries**	**Total NRS Pain Score**
Head/Neck	3	0	0	3	11
Shoulder	0	0	0	1	5
Elbow	1	0	0	0	0
Hand/Wrist/Fingers	4	1	26	1	6
Chest	1	0	0	0	0
Trunk/Back/Buttocks	3	3	15	5	21
Thigh	2	3	26	4	13
Knee	3	2	231+	4	17
Lower Leg	4	2	9	4	13
Ankle	4	3	35	1	7
Foot/Toes	1	0	0	1	2
Total	**26 (41%)**	**14 (22%)**	**342**	**24 (37%)**	**87**

4.3.12 In Figure 14 the events causing the injuries, for those related to a specific event, typically acute injuries, are presented. The graph shows the most common events resulting in injury were running (14%, n=9) and being struck by another player (13%, n=8). Variations in the cause of injury was demonstrated across injury sites. Similar injury causes were observed at some injury sites, including the head/neck (struck by another player), hand/wrist/fingers (struck by ball), foot/toes (running) and lower leg (running). In the acute trunk/back/buttock injuries causes included being struck by another player, running and landing from a jump. Thigh injuries resulted from a wider range of causes however, the largest variation in injury causes was observed at the knee and ankle. Ankle injuries were a result of landing from a jump, changes of direction, running, collisions and being struck by a player and decelerating. Knee injuries resulted from a similar range of events with the 2 most severe injuries identified in Table 1 resulting from being struck by another player (knee sprain) and landing from a jump (ACL rupture).



4.3.13 The ankle taping and bracing practices of players experiencing lower extremity injuries revealed players wore ankle tape in 56% of knee injury cases, 38% of ankle injury cases, 60% lower leg injury cases and 100% foot/toe injury cases. Ankle braces were worn by 11% of players with knee injuries, 10% of lower leg injuries and 13% of ankle injuries. 22%, 30% and 25% wore no taping or braces when sustaining knee, lower leg and ankle injuries, respectively.

Limitations

It should be acknowledged that there were some factors which impacted upon the findings of this injury surveillance study.

- The main limitation of the research is that the results represent the injuries sustained within only 4 out of the 10 teams that competed in the VNSL 2019. Although 7 teams initially agreed to take part in the study and player consent forms were received from 6 teams only 4 recorded any injury data. Injury data from all 10 VNSL would provide a more complete understanding of the injury issues in the elite competition.
- As the new injury surveillance system for 2019 was set up in a relatively short space of time (November to December 2018) there was limited time an opportunity to fully explain the system to the team physiotherapists prior to the start of the competition. While those physiotherapists who captured their team's injury data provided valid and useful injury data the recording consistency across physiotherapists may have been impacted by the limited training opportunities.
- Injury incidence rates in the VNSL 2019 competition were calculated based on player

match and training exposure data. The exposure data was based on the total number of matches and average training hours and sessions. More accurate records of individual player match-play and training hours will enable increased accuracy of incidence rates. Furthermore, this information will allow the relationships between training and playing load and injuries to be determined in future.

Summary

This section includes a summary of the main findings from the injury surveillance of the 2019 VNSL. It should be noted that the limitations stated above will have impacted the overall findings, hence they provide an indication of the injury issues in the competition but not a comprehensive assessment.

6.1 The new injury surveillance system developed and implemented in the VNSL 2019 has provided a detailed assessment of injuries and their associated factors. Adopting the current methodological directives from injury research enabled assessment of injury relationships through the identification of different types of subsequent injuries. Furthermore the use of a broader medical attention definition of injury allowed the surveillance to capture more transient and overuse injuries providing a more complete picture of the injuries that occur in the competition.

6.2 From the injury surveillance conducted on 4 teams in the VNSL 2019 the main findings were:

- The baseline data revealed over half the players who consented to take part in the study had sustained an injury in the year prior to the VNSL 2019. Just under half had also sustained a major injury or surgery leading to a minimum of 6 weeks absence from the sport. Considerable team variation in the number of players injured in the 6 weeks prior to the competition start may indicate differences in current injury prevention practices across teams.
- The player training and match exposure hours allowed the calculation of incidence rates per 1000 exposure hours. A total of 64 injuries from 53 players equated to an overall injury incidence rate of 5.15 injuries per 1000 exposure hours. The total number of injuries recorded compares favourably to the 59 injuries reported in the 2016 injury audit[6] but is greater than the 29 injuries recorded in 2018. Differences in injury surveillance methods will affect the injuries reported particularly variations in the definition of injury. This may partially account for the differences in injuries recorded across seasons. In 2016 a higher injury incidence rate of 9.08 injuries per 1000 hours exposure was reported but it is not known whether this injury rate included training exposure in addition to match exposure making comparison

difficult.

- Although slightly more injuries were recorded in training (n=34, 53%) compared to matches (n=30, 47%) in the 2019 competition, when the separate incidence rates are calculated and exposure hours taken into account, the training incidence rate of 4.58 injuries per 1000 hours is lower than the match rate of 5.99 injuries per 1000 hours. Hence the importance of calculating the rate of injuries to identify the true injury picture. Previous VNSL injury audit's in 2016 and 2018 both reported a higher number of injuries in matches compared to training (2016: 71% and 29%, 2018: 59% and 31% respectively). The different finding in the 2019 data may again result from differences in the methods of surveillance across seasons, particularly in the injury definitions used, thus consistency of injury surveillance methods is important for future competitions to develop an accurate injury evidence base.
- A new addition to the 2019 injury surveillance was the assessment of the relationship between injuries known as subsequent injuries. 31 of the 53 players assessed sustained at least 1 injury during the 2019 competition. A high proportion of these injured players (n=21, 68%) sustained a total of 48 subsequent injuries, either a new subsequent injury unrelated to the previous index injury, or a local injury (same site different type to index injury), or recurrent exacerbation (unhealed injury at same site and type as index injury). New subsequent injuries were the most common type of subsequent injury (n=33, 69%) with recurrent exacerbations (n=12, 25%) the most common recurrence. 80% of exacerbations were overuse conditions and 4 players experienced 2 exacerbations of the same injury thus managing such conditions across a season is an important consideration.
- In the 2019 VNSL most injuries were acute (n=41) and occurred due to both non-contact (n= 24) and contact events (n=17). 23 overuse injuries by comparison were all related to non-contact events. This surveillance also recorded an equal number of acute and overuse training injuries but match injuries were mostly acute in nature.
- Overall most injuries in 2019 were recorded within the first 2 months of the competition. This pattern was also seen during training activities but a peak in match injuries occurred in month 3 with slightly lower numbers recorded in the first 2 months. These findings agree with the 2016 audit which reported a higher injury frequency in the first half of the season but differ from the 2018 audit which recorded a higher injury frequency during months 3 and 4.
- C and GS positions sustained the majority of injuries in the 2019 competition with and equally high frequency in both training and matches. The GK position also

sustained a higher frequency of injuries but mostly during matches. The fewest injuries were reported in players in the GD position. These findings are somewhat similar to those of 2018 which also reported a high frequency of injuries in the GS and C positions but found the WD position to be most commonly injured. The 2016 audit found no significant association between playing position and injury incidence.

- The majority of injuries in 2019 were recorded in the 4th quarter of the match. Although the time of injury was unknown in 23% (n=7) of the recorded injuries this general finding is consistent with the 2018 injury audit which also reported most injuries within the 4th quarter. The 2016 audit however reported an increased injury frequency within quarter 3. Furthermore, half of the 4th quarter injuries in 2019 were reported in minutes 5-10 of the quarter.
- As is frequently reported in Netball injury research, the lower extremity (knee, lower leg, ankle and foot/toes) recorded a high proportion of injuries in 2019 accounting for 45% of the 64 injuries. The lower leg (particularly the calf), knee and ankle were the most common injury sites. A range of acute sprains, strains and overuse muscle tendon injuries were most frequent at these sites. The 2016 and 2018 audits reported the ankle and knee respectively to be the sites most frequently injured but in comparison to these findings the 2019 seasons data reported the highest frequency of injury in the trunk/back/buttocks with back injuries most frequent. In 2018 no back injuries were recorded, differences in injury definitions and data recording methods may partly explain this finding. Most back injuries were overuse conditions, thus the broad injury definition used in the 2019 surveillance may have facilitated the capture of a greater number of overuse injuries.
- In addition to being one of the most frequent injury sites the knee also reported the highest injury severity. 2 acute knee injuries, 1 of major severity (28 days to 6 months) and the other long-term (>6 months) resulted in approximately 231 days lost from the sport. In addition, 4 overuse non-time loss knee injuries resulted in a total NRS pain score of 17. The back injuries recorded were also of relatively high severity with a total of 15 days lost from time-loss injuries and an accumulative pain score of 21 from non-time-loss injuries. Acute injuries at the ankle resulted in a total of 35 days lost from the competition.
- The events causing injuries were largely related to the site and type of injury. Typically head/neck, hand/wrist/finger, foot/toes and lower leg injuries were caused by the same or a small number of events e.g. hand/wrist/finger injuries were mostly caused by being struck by the ball. However, a wider range of events led to injuries at the knee and ankle in particular. The events included landing from a jump,

changes of direction, running, collisions and being struck by a player.

- Those players experiencing lower extremity injuries particularly at the knee and ankle reported variation in taping and bracing practices. A total of 67% of players sustaining knee injuries reported wearing ankle tape or braces and 51% of players with ankle injuries.
- The injury data recorded across the 4 teams who took part in the VNSL 2019 injury surveillance showed variation in the total number of injuries recorded and the number and types of subsequent injuries observed. However similar patterns of injuries were reported in terms of injury mode, month of injury, injury positions, the time of injuries in matches, the most frequent injury sites and their causes.

Conclusions and Future Developments

7.1 Conclusions

- The injury surveillance system developed to assess injuries in the 2019 VNSL competition has incorporated up-to-date research directives to ensure the injuries occurring in the competition are accurately identified.
- The injury data recorded in the 2019 competition has provided some initial evidence of the extent of injuries and their associated factors across 4 VNSL teams. The findings from the 2019 injury surveillance reveal both differences and similarities to the two previous injury audits.
- To develop an accurate injury evidence base for elite netball in the UK, which will inform effective preventive strategies, further injury surveillance data over subsequent seasons is required using a consistent methodology.
- Furthermore it is crucial that injury data is accurately recorded from all teams across subsequent seasons if the true injury issues and their related factors are to be identified in the VNSL.

7.2 Future Developments

- To facilitate a greater number of teams actively recording their injury data in the 2020 VNSL training will be conducted at the VNSL Forum on 13th November 2019. The training will focus on fully explaining the injury surveillance system and how to record data accurately and consistently. Opportunity will be provided to discuss the data recording process with relevant parties including the physiotherapists who recorded data in 2019.
- To facilitate the recording of more accurate match exposure data it has been requested for match officials to record the actual time individual players participate

in the match. It is hoped more accurate individual player training exposure/load can be recorded with the assistance of team strength and conditioning staff. This information will allow increased accuracy in the calculation of injury incidence rates and further investigation of the relationship between load and injuries.

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Appendices

Injury Surveillance Report Forms.

Vitality NSL 2019 Player Baseline Information Form

Team Code:									Details of Previous Injuries :		
Player ID Code	Playing Positions ≠	Age (years) †	Height (cm)	Body Mass (kg)	Dominant Side (L/R/B) ≈	Do you regularly tape your ankles for training? Yes/No	Do you regularly tape your ankles for matches? Yes/No	Do you wear any braces - Ankle/Knee?	1) Within the last 6 weeks:	2) Within the last year:	3) Any previous major injuries or surgey which resulted in more than 6 weeks out of sport. Please state the specific injury e.g, ACL rupture, reconstructive surgery.

Figure 1: VNSL 2019 Player Baseline Information Form

Vitality NSL 2019 Player Exposure Form

Team Code:	ISS5	Date:	
Player ID Code:	VNSL Training minutes (Includes squad Netball sessions, weights sessions and other conditioning sessions)		VNSL Match minutes (includes Warm-up and match play minutes) *Completed by researcher

Figure 2: VNSL 2019 Player Exposure Form

Vitality NSL 2019 Player Injury Report Form

Team Code:

	Injury Information											Injury Classification		
Player ID Code	Date of Injury	Training or Match injury	Quarter and Time of injury during Match	Playing Position	Started Game or Substitute?	Mode of Onset (Acute or Overuse)	Contact or Non-Contact Injury?	Protective Equipment worn at time of Injury	Training Injury Activity	Event Causing Injury	Other Event not listed (please specify)	Index Injury	Subsequent Injury	Multiple Injuries

Injury Diagnosis					Initial Treatment					Injury Severity and Recovery (Time-Loss Injuries)				Injury Severity and Recovery (Overuse Non Time-Loss Injuries)		
Body Region Injured	Nature of Injury	Other Region/Nature (please specify)	Injured Side	Specific Diagnosis (please specify)	Initial Treatment	Other Treatment (please specify)	Initial Treatment Outcome	Referral	If referred, diagnosis outcome (please specify)	Total no. days lost	Partial Return to Play Date	Full Return to Play Date	Injury Healed Date	Initial Pain Level	Please provide any further details of changes in pain level and functional capacity of overuse injuries. Include dates of assessment.	Injury Healed Date

Figure 2: VNSL 2019 Player Injury Report Form

Injury Report Form Completion Instructions:	Definitions continued:
1) Please report each new Injury occurring during the VNSL competition (in both training and match-play) on your teams Injury Report Form in the Injury Report Form Worksheet (accessed below). This includes a new entry for each Subsequent Injury and Multiple Injury.	**Index Injury:** The first injury in a series of injuries constituting a recurrent condition. **First Index Injury**: The first injury that occurred during the VNSL competition. **Subsequent Injury**: any injury occurring after the first index injury during the VNSL competition.
2) Every time a player experiences an injury (as defined below) enter the players unique ID code and date of the injury followed by the relevant information associated with the injury.	3 Types of Subsequent Injury: 1) **Subsequent New Injury** (completely different location to Index Injury) 2) **Local Injury** (same location but different type to Index Injury) 3) **Recurrent Injury (Exacerbation)** (same site and type as index injury but Index injury not fully healed at time of recurrence), **Recurrent Injury (Reinjury)** (same site and type as index injury, Index injury fully healed at time of recurrence).
3) All responses require you to either: type the relevant information into the appropriate box or select the relevant options in the drop-down lists. If a grey arrow appears on the right hand-side of a data entry box you are required to select from a list. In some cases if the relevant response is not in the drop-down list you are provided with a space to type the information.	**Multiple Injuries:** more than one injury occurring in a single event e.g. ankle sprain and wrist sprain from an awkward landing. **Time-Loss Injuries**: any injury that results in time (at least 1 day) lost from training or matches. These include both acute injuries and some overuse injuries which result in days lost.
4) The first injury for each player during the VNSL is recorded as a "First Index Injury". A further injury for each individual player is then reported as a subsequent injury. Please see the definitions here which define the different type of subsequent injury. If more than one injury occurs in one event please also record it as a multiple injury and report each injury on a new line.	**Total number of days lost:** the severity of time-loss injuries are defined by the total number of days lost from training and matches recorded from the date of the injury to the full participation in training and availability for match selection. If a player can fully participate the day after the injury occurs the injury is recorded as a severity of "0" days. If they cannot fully participate this is 1 day lost and so on.
5) The Injury Diagnosis requires you to select the appropriate Body Region and Nature of Injury and provide written details of the specific injury diagnosis.	**Overuse Non-Time Loss Injuries:** an overuse injury may result in continual or sporadic pain or discomfort but not prevent players from training and playing in matches. Thus an overuse Non-time loss injury is any injury evaluated by the Physio that did not result in time-loss from training or matches.
6) Please enter as much information as possible regarding each Injuries level of Severity and Recovery. This information will need to be updated as the players injury changes/recovers. If an injury is not fully healed at the end of the VNSL please provide an estimated period of time loss.	**Pain Level:** the severity of non time-loss overuse injuries are defined by the level of pain experienced by the player. Rate the athletes level of pain using an 11 point numeric scale with 0 indicating "No Pain" and 10 indicating "worst pain imaginable" (Numeric Rating Scale for Pain (NRS)).
7) Should you have and questions or queries during the competition when reporting your injury data you can contact me at Sara.horne@brunel.ac.uk or on 07815932499. Many thanks for you time.	**Functional Capacity:** as well as pain players with overuse injuries may experience additional symptoms including swelling, instability, reduced strength, limited range of motion and reduced agility which limit their functional capacity. Please report any functional limitations resulting from the overuse injury. Please also state if the initial Overuse Non-Time Loss injury becomes a Time-Loss injury.
Definitions:	
Injury Definition : A reportable Injury is one that occurs as a result of training or match-play in the VNSL and which led to one of the following consequences: 1) Medical attention or advice (from team Physiotherapist and/or other medical professional), 2) Time-Loss (a reduction in the amount or level of Netball activity).	**Healed Injury:** a fully healed injury is one where the player has returned to full participation and/or is no longer receiving medical treatment or is no longer experiencing pain symptoms. Note: For Time-Loss injuries this may be after the player has returned to full participation. Some injuries may not fully heal during the VNSL competition please provide an estimated healed data where possible.
Training: any physical activities under the control or guidance of the team's coaching or fitness staff aimed at maintaining or improving players netball skills or physical condition.	
Acute Injury: injury resulting from a specific, identifiable event e.g. ankle sprain **Overuse Injury**: injury caused by repeated micro-trauma without a single, identifiable event e.g. shin splints	

Figure 3: Injury Report Form Instructions and Definitions

Vitality Netball Superleague 2021 Injury Surveillance Report

SUBMITTED TO ENGLAND NETBALL ON 10/1/21

Sara Horne, Laura Hills, Aliah Shaheen and Bill Baltzopoulos

Sport, Health and Exercise Sciences, College of Health and Life Sciences

Background

- As part of this PhD netball injury research, data was collected from the 2019 Vitality Netball Superleague (VNSL) competition. This study used an injury surveillance tool developed by the lead researcher from the existing VNSL injury audit. Data from 4 VNSL teams was collected and the findings reported to England Netball (EN) and at the 2020 VNSL Forum.
- Following this initial injury surveillance EN decided to adopt a digital medical records system (PDMS) managed by the English Institute of Sport (EIS). The reporting of injury data by each VNSL team's physiotherapist using the PDMS system became a mandatory part of their role.
- Injury data collection in the 2020 VNSL competition subsequently used the PDMS system. Furthermore, EN began the trial of tracking devices to inform players' physical preparation and minimise injury risk. However, as a consequence of the Covid-19 pandemic the VNSL competition was cancelled in March 2020. Thus, a full set of injury data was not collected from the 2020 VNSL season.
- EN received agreement that the 2021 VNSL competition could go ahead with appropriate Covid-19 restrictions.
- 11 VNSL teams took part in the 2021 competition (one additional English-based team joined the League in this season). Nine teams were based in England, with 1 in Wales and 1 in Scotland.
- The competition took place from 12th Feb to 27 June, with 20 rounds, 2 semi-finals, a 3rd, 4th final and a grand final conducted over 16 weeks. In total 112 matches took place at 2 central venues. The first 11 rounds (9 weeks) of the competition took place in Wakefield, in the North of England, and the remaining 9 rounds, Semi-Finals and Finals took place at the Copper Box in London. All matches took place behind closed doors with no crowds. An extensive season-long Covid-19 testing programme was put in place.
- In previous seasons fixtures were played home and away, at each team's venues. The tournament consisted of 18 rounds plus 2 semi-finals and a final, conducted over 20 weeks. To adjust for the slightly condensed season in 2021 the match lengths were changed from 4 x 15-minute quarters to 4 x 12-minute quarters. Furthermore, 5 weekends across the 2021 season included 2 rounds played over 4 days between Friday-Monday.
- This report presents the findings from the injury surveillance conducted during the VNSL 2021 competition.

Methodology

- A prospective cohort design was used to assess the incidence and characteristics of injuries during the 2021 VNSL competition.
- EN approved the conduction of the research in the VNSL competition and ethical agreement was provided by the College of Health, Medicine and Life Sciences Ethics Committee at Brunel University.
- All 9 English-based teams were forwarded information regarding the study prior to the start of pre-season training. On receiving team agreement individual players were forwarded the same information and asked to provide their informed consent to participate in the study.
- All 9 English team's Physiotherapists were given access to the PDMS system to record their team's injury data. Prior to use they were provided with clear guidance regarding how to use the system and the information required.
- The injury definitions used were the same as the 2019 injury surveillance study. A reportable injury was defined as one that occurs as a result of training or match-play in the VNSL 2021 and which led to one of the following consequences: 1) Medical attention or advice (from team physiotherapist and/or other medical professional), 2) Time-Loss (a reduction in the amount or level of netball activity). A more inclusive definition was selected to include minor, transient injuries and overuse injuries not resulting in time-loss to gain a more complete picture of the full range of injuries in the competition.
- The injury data collected from the PDMS system includes the injury occurrence date, resolved date, activity at time of injury (competition/training/other), the injury cause, the body region injured, injury diagnosis, injury severity described by the total duration of the injury in days, medical attention days, restricted days and unavailable days.
- The EIS provided access to the PDMS injury data of all athletes providing study consent. The data was collected during pre-season (from 1 September 2020 to the competition start on 12 February 2021) and across the 20 rounds, semi-finals and final. Details of player injuries prior to pre-season that were ongoing in-season were also collected. All data was subsequently coded to ensure player anonymity and data protection.
- Injury data from the VNSL 2021 were analysed to identify an overall injury incidence rate and separate incidence rates for training and match injuries. The total number of new injuries recorded during pre-season and the competition were used to determine incidence rates. Injury incidence rates were calculated by dividing the number of injuries by the hours of exposure and multiplying by 1000 to obtain the injury incidence per 1000

player hours.

- Descriptive analysis of injuries according to overall player injury frequency, subsequent injury frequency, injury activity and mode, month of injury, injury position, time of injury in the match, injury site and injury severity and cause (mechanism) was conducted. Data are presented as the total percentage injuries or number of injuries across all teams and as percentage match and training and acute an overuse injuries where appropriate.

Results

7 of the 9 English teams in the VNSL 2021 provided consent to take part in the study. Subsequently, individual player consent was gained from 91 players from these 7 teams. 1 player withdrew prior to the start of the season on medical grounds.

Baseline Data

The mean player age and height was 24 years and 179.3 cm. Ankle taping for training and matches was used by 30% and 37% of players, respectively. 13% of players used ankle braces on at least 1 ankle. The use of taping/braces varied considerably across teams.

28 players (31%) had experienced at least 1 previous major injury requiring surgery and/or at least 6 weeks out of the sport. These injuries included: 43% at the knee, 32%-ankle, 14%-foot, 7%-elbow and 4%-back. 8 players had previously experienced major ACL injuries; 3 of whom had ruptured the ACL in both Knees.

11 players had pre-existing injuries which were unresolved prior to start of the 2021 VNSL season. These injuries were mostly located at the knee (73%, n=8), with 1 injury at the ankle, foot and leg. The 11 pre-existing injuries at the knee (n=8) included 2 ACL sprains, 1 meniscal tear, and a range of overuse injuries including patella tendinopathy, patellofemoral pain syndrome, synovitis and iliotibial band friction syndrome. The other injuries included ankle tendinopathy, foot bone stress and retrocalcaneal bursitis. 1 ACL knee injury impacted the players participation for part of the season. All injuries required continued medical attention in the 2021 VNSL season.

Exposure Data

For the 7 teams taking part in the study match exposure hours were calculated as the number of player hours multiplied by the number of matches. The total playing hours equated to 1015 playing hours.

The teams training exposure hours were reported by the team Physiotherapists in the baseline data. Average training hours were multiplied by the number of training weeks, including pre-season training from start of September 2020 to the start of the competition on

12 February 2021. The total training hours equated to 4178 hours.

Injury Incidence Rates

A total of 74 new injuries were reported in 40 players (44%) during the 2021 VNSL competition. 50 players (56%) incurred no injuries.

33 of the 74 new injuries occurred during matches. This equates to an injury incidence of 32.5 injuries per 1000 playing hours.

35 of the 74 new injuries occurred during training. This equates to an injury incidence of 8.38 injuries per 1000 training hours.

Overall, the total injury incidence rate for the VNSL 2021 competition equates to 13.1 injuries per 1000 playing and training hours.

The PDMS medical record system also reported 6 injuries that occurred outside of VNSL playing or training activities during the competition timeframe. These injuries are not included in the incidence rate calculation. However, they are included in the following injury descriptions as they will impact the players and teams during the competition.

It is also important to note that considerable variation was seen in the number of injuries recorded across teams. The number per team ranged from 3 to 31 injuries.

Injury Surveillance Data

<u>Frequency of injuries per player:</u>

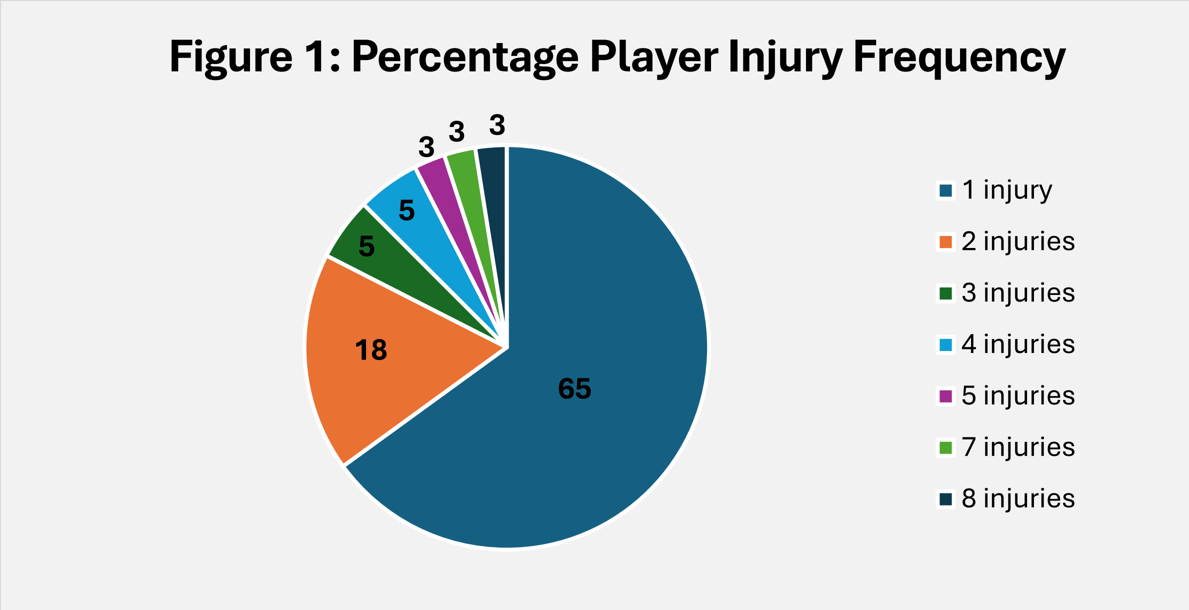
The percentage injury frequency in the 40 injured players is identified in Figure 1. Most players (n=26) sustained 1 new injury (65%), with 18% (n= 7) sustaining 2 injuries. 2 players (5%) sustained 3 or 4 new injuries, and 1 player (3%) sustained 5, 7 or 8 injuries during the competition.

<u>Recurrent Injuries:</u>

In addition to the new injuries, 7 injuries recurred during the competition. 5 players experienced 1 recurring injury and 1 player incurred 2 different recurring injuries.

<u>Injury Activity (pre-season, training or match):</u>

A total of 23 (31%) of the new injuries occurred in the pre-season period (1 September to 11 February) while 51 (69%) occurred during the 5 months of the competition (12 February to 27 June). Figure 2 shows the overall (combined pre-season and in-season) percentage of new injuries that occurred during training, matches or other activities. A slightly greater

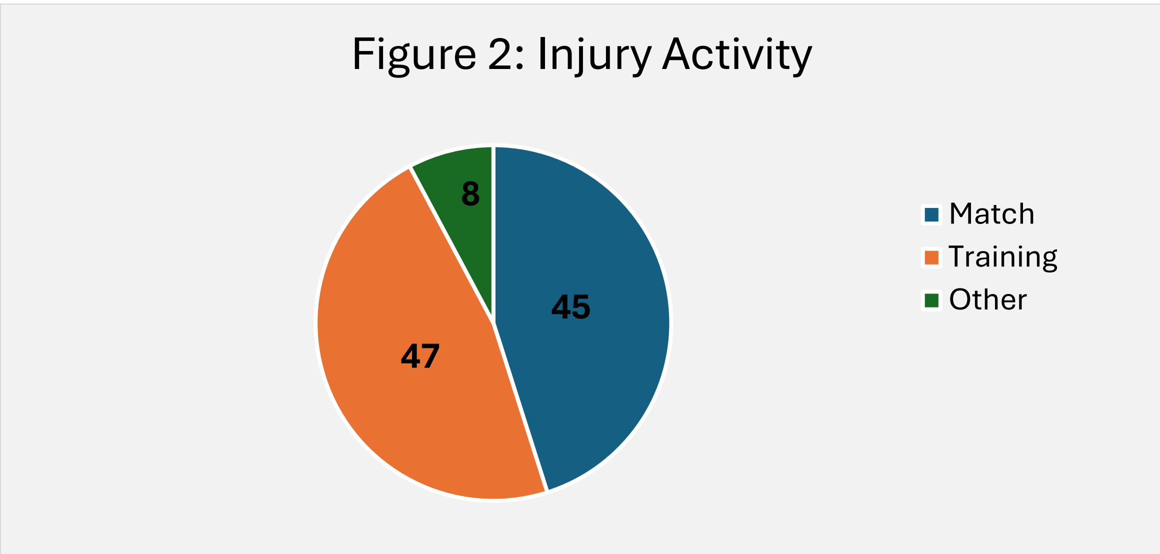


percentage of injuries occurred during training activities (47%, n=35), compared to match-play (45%, n=33).

During the pre-season period 17% of injuries (n=4) occurred during matches, while 65% (n=15) occurred in training and 17% (n=4) during other activities.

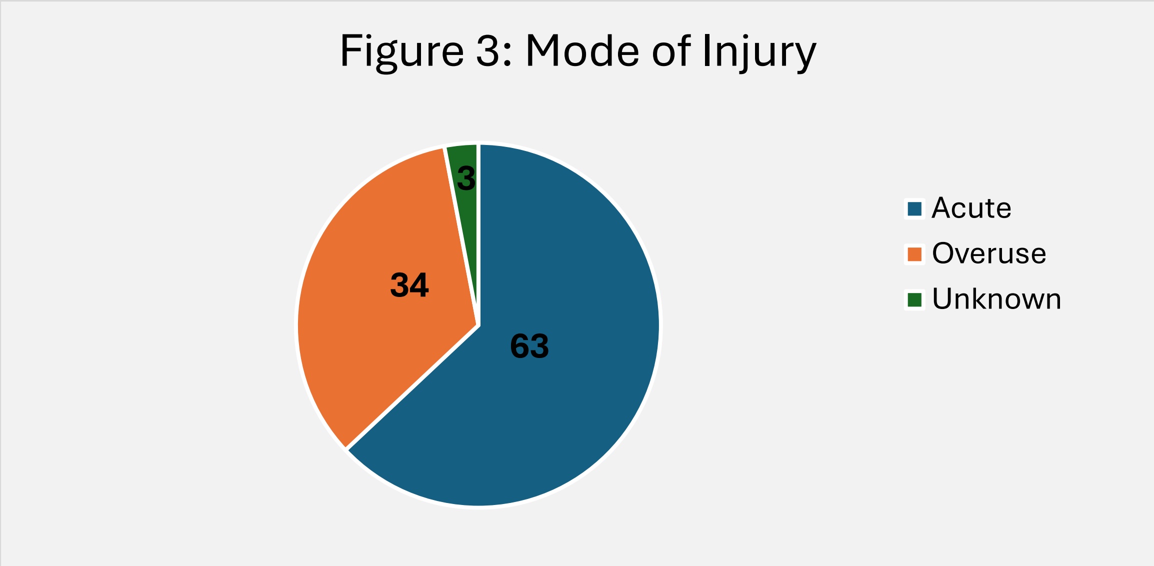
During the VNSL 2021 season (in-season period) 57% of injuries (n=29) occurred during matches, with 39% (n=20) in training and 4% (n=2) during other activities.

Of the 7 recurrent injuries that occurred during the VNSL 2021 season, 43% (n=3) were attributed to matches and 57% (n=4) to other activities. No injuries recurred as a result of training activities.



Mode of Injury

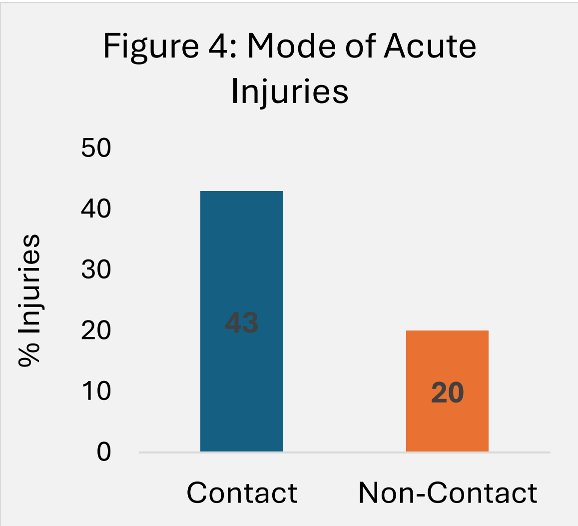
The mode of injury presented in Figure 3 shows that a higher percentage of new injuries were acute (63%, n=47) compared to overuse (34%, n=25). The mode of injury was unknown in 3% (n=2) cases.

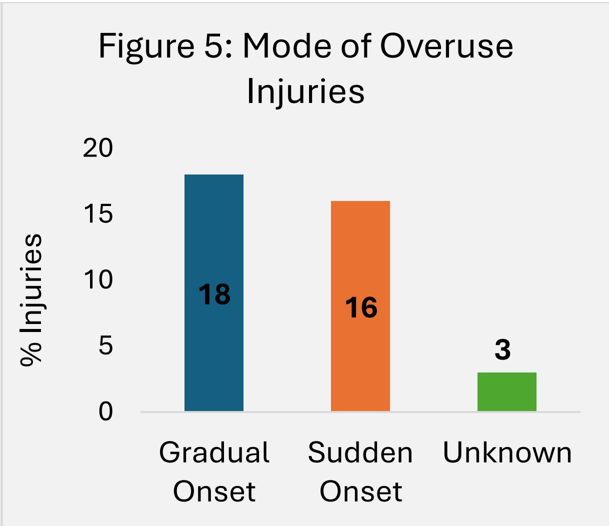


Figures 4 and 5 show that 43% of all new injuries (n=32) were acute contact injuries while 20% (n=15) were non-contact acute injuries. A further 18% (n=13) of overuse injuries were of sudden onset with 16% (n=12) resulting from a gradual onset.

Of the 47 acute injuries 68% were contact and 32% non-contact injuries.

Of the 25 overuse injuries 52% were gradual onset and 48% sudden onset.

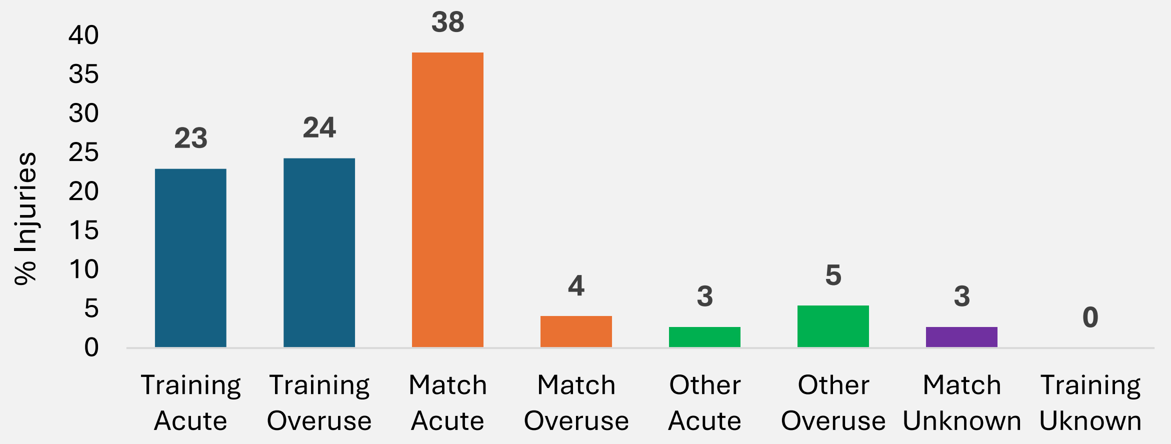




Activity and Mode of Injury

Figure 6 shows the percentage new injuries for activity and mode combined. The highest percentage of injuries were acute injuries during matches (38%) which were considerably more frequent than overuse injuries during matches. Of the 33 match injuries this equates to 85% acute, 9% overuse with 6% unknown. In comparison, the injuries during training were more evenly attributed to acute or overuse causes. Of the 38 training injuries 55% were overuse and 45% acute injuries. The “other” injuries (n=6) occurring outside of the competition were mostly overuse (67%) with 33% acute in nature.

Figure 6: Activity and Mode of Injuries

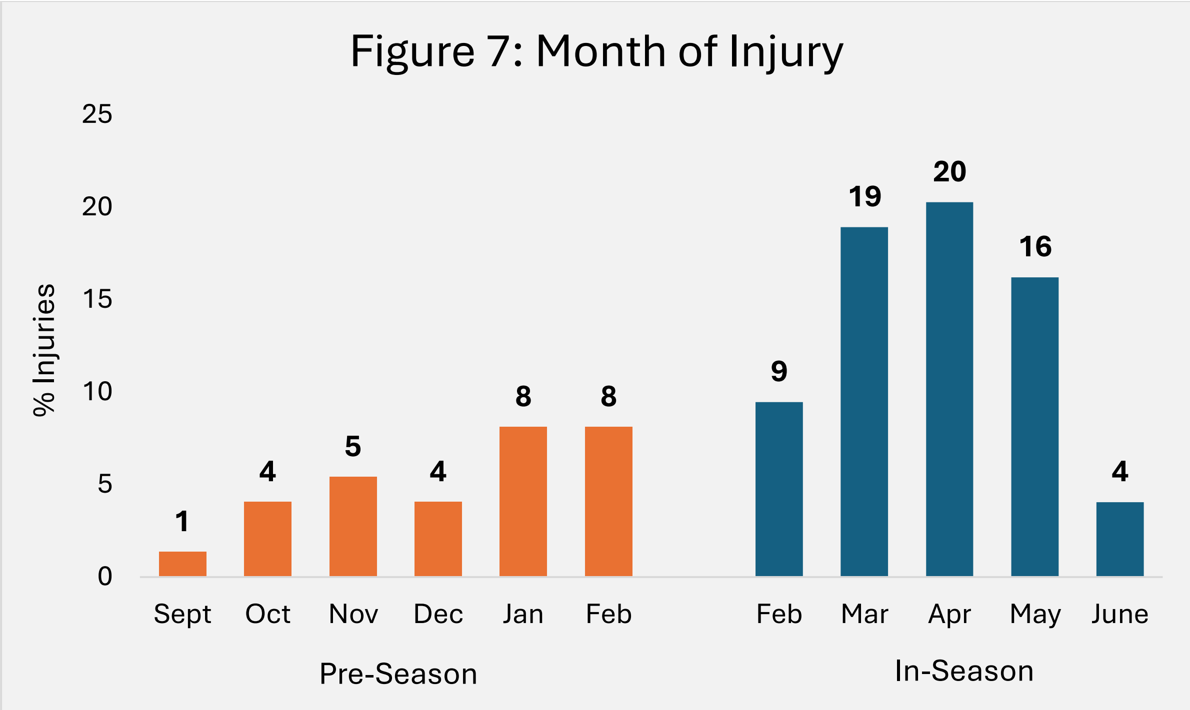


Month of Injury

Figure 7 identifies the percentage new injuries that occurred in the pre-season and in-season months of the VNSL 2021 competition. The graph shows an increase in the percentage injuries as the pre-season progressed. The percentage injuries increased across February as the competition started (12^{th} February) and further increased through March (19%, n=14 injuries) to a peak in April (20%, n=15 injuries). From May the percentage injuries started to decline with a considerable decrease in June.

The in-season injuries may partially relate to the number of matches the 7 teams assessed played across each month. The lowest number of matches were in February (n=18), with 24 in April 26 in May and 12 in June, when the lowest percentage injuries occurred.

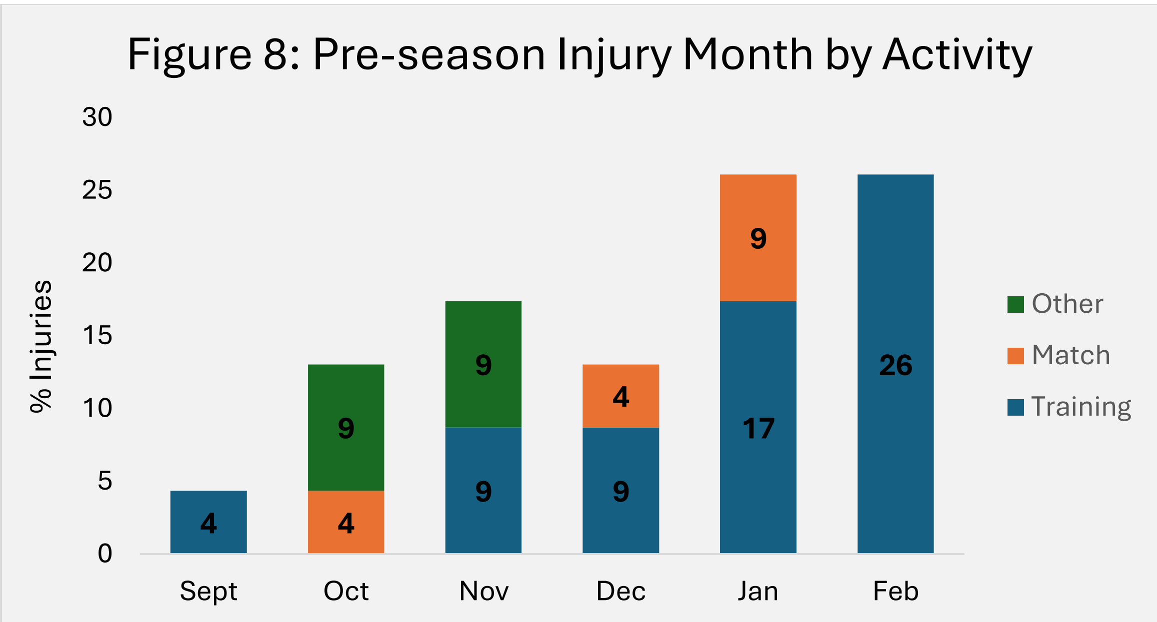
3 of the recurrent injuries recurred in February at the start of the competition. A further 3 injuries recurred in April with 1 in June.

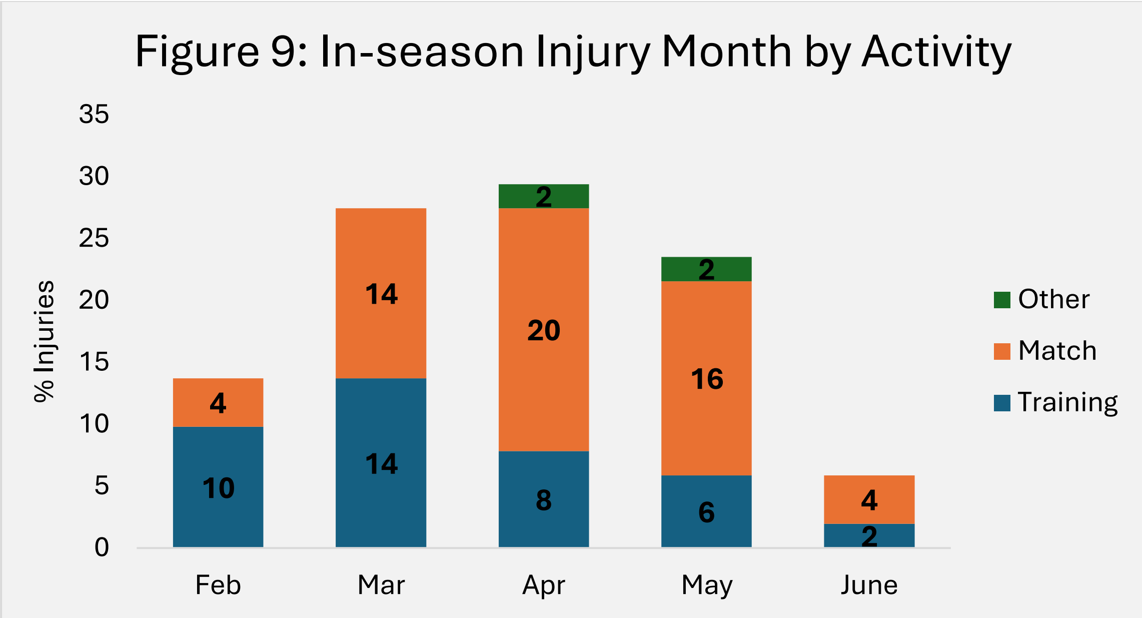


Figures 8 and 9 show the percentage new injuries occurring each month by activity (match, training or other), during the pre-season and in-season periods, respectively.

The pre-season graph (Figure 8) shows a higher percentage of training injuries in comparison to match injuries from November through to the start of the season. These training injuries also increased from December with the highest percentage in the first half of February prior to the season start.

The in-season graph (Figure 9) shows a gradual change from a higher percentage of training injuries to a higher percentage of match injuries from April through to the end of the season.

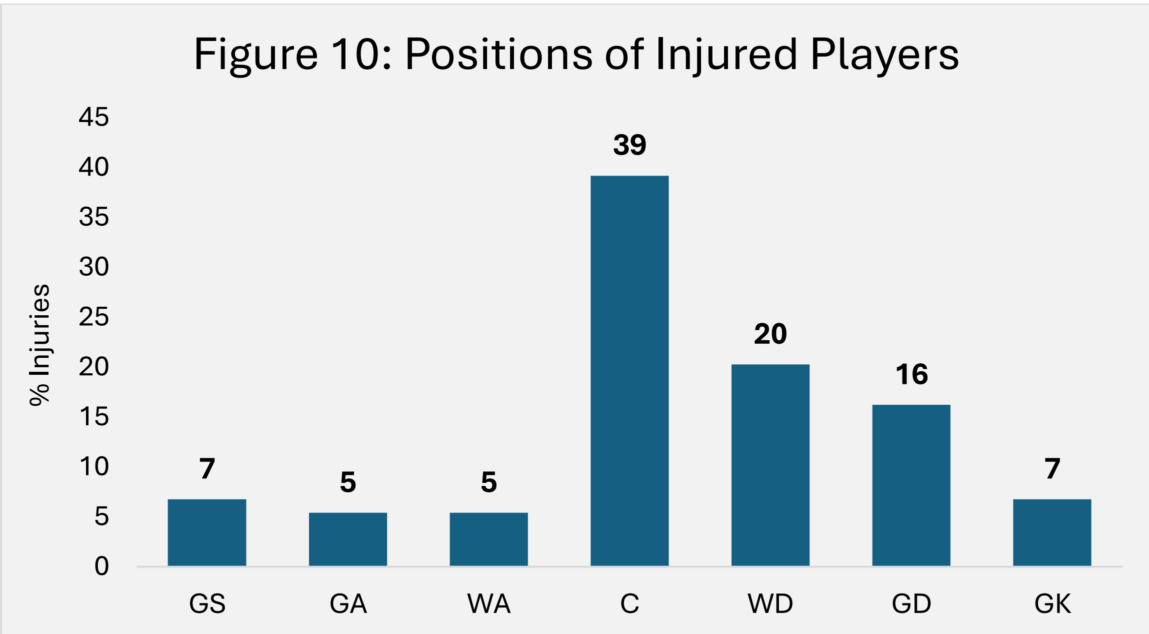




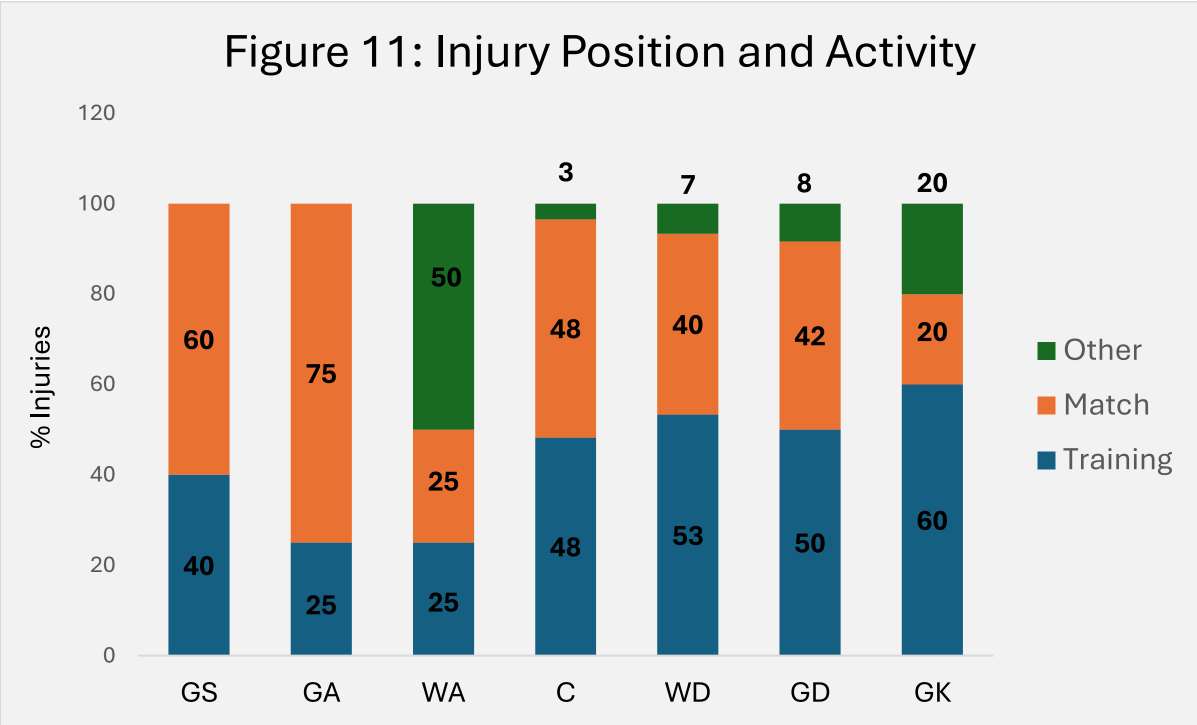
Injuries by Playing Positions

Figure 10 displays the distribution of injuries across the 7 netball playing positions. Most injuries in the 2021 competition occurred in the C (39%, n=29), WD (20%, n=15) and GD (16%, n=12) positions with the lowest injuries in the GA and WA (5%, n=4) positions.

The 7 recurrent injuries occurred in the following positions: C (29%, n=2), WA (29%, n=2), WD (29%, n=2) and GD (13%, n=1).



The activity leading to injury for each position is identified in Figure 11. A greater percentage of injuries in the defensive players (GK, GD and WD) occurred during training activities. In contrast a greater percentage of injuries in the shooters (GS and GA) occurred during match-play. The mid-court WA and C positions had an even percentage of injuries during training and match-play.



<u>Anatomical site of Injuries</u>

The site of injuries in the VNSL 2021 are presented in Figure 12. Of the 74 new injuries across the 7 teams most 77% (n=57) were located at the lower extremities (ankle, foot, knee, leg, thigh and hip/groin), shown in red. Ankle (34%, n=25), leg (16%, n=12) and knee (12%, n=9) injuries were the most frequent lower extremity injuries. The trunk (shown in green) accounted for 8% of the injuries with 5% (n=4) in the lumbar/pelvis area and 3% (n=2) in the thoracic/ribs region. Upper extremity injuries (blue) accounted for 7% of all injuries with 3% (n=2) at both the shoulder and hand and 1% (n=1) at the forearm. Unusually head injuries (purple) accounted for 8% (n=6) of the injuries occurring in the competition.

The site of the recurrent injuries was the ankle (29%, n=2), knee (29%, n=2), leg (29%, n=2) and the shoulder (13%, n=1).

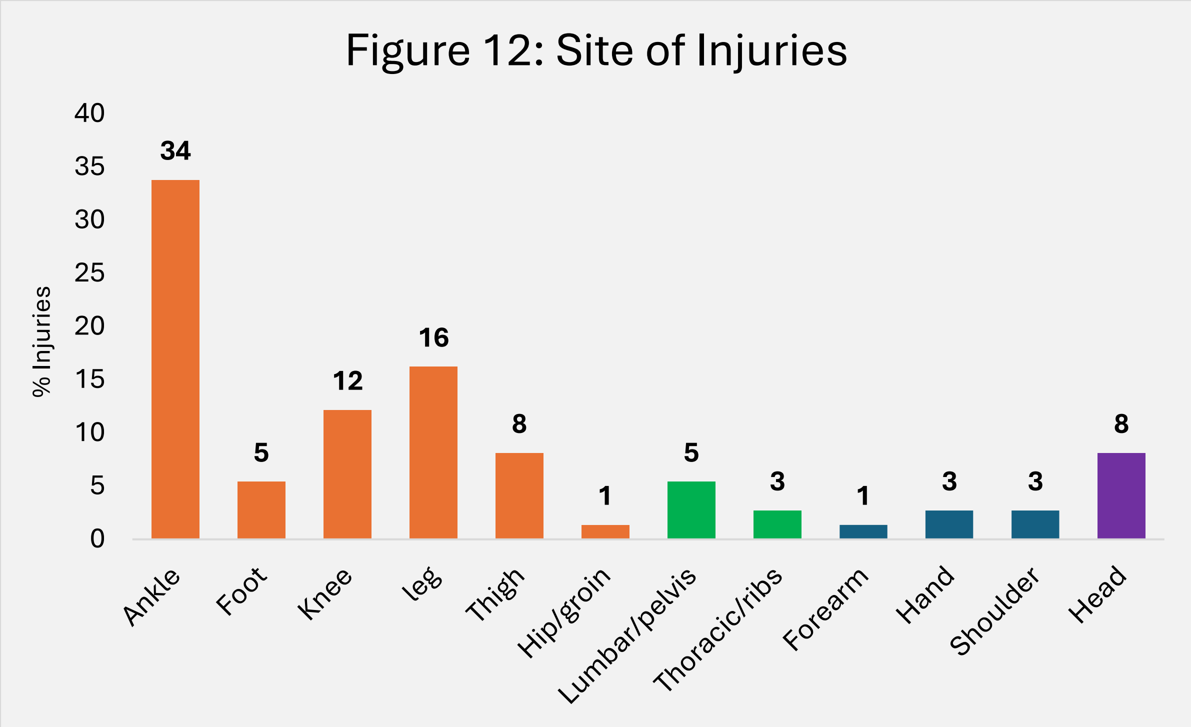


Figure 13 shows the percentage injuries at each site during training, matches and other activities. A greater percentage of injuries at the foot, knee, leg, thoracic/ribs, shoulder and head occurred during training activities. Conversely, a greater percentage of injuries at the ankle, thigh, hip/groin, lumbar/pelvis and forearm occurred during match-play. An equal number of hand injuries occurred during training and match-play.

Figure 14, shows the percentage injuries at each site by the mode of injury. Injuries at the hip/groin, forearm, hand and head were all acute, contact injuries. Injuries at the ankle were largely acute with a relatively even percentage of contact (44%, n=11) and non-contact injuries (48%, n=12). Foot and leg injuries were all overuse with a higher percentage of gradual onset injuries (75%, n=3 and 58%, n=7 respectively). The majority of knee injuries were acute non-contact injuries (44%, n=4), but 33% (n=3) were also sudden onset overuse injuries, with 1 acute contact and 1 overuse gradual onset injury. Lumbar/pelvis and thigh injuries were also mostly acute while injuries at the shoulder and thoracic/ribs showed an even distribution of acute and overuse injuries.

Figure 13: Site of Injuries and Activity

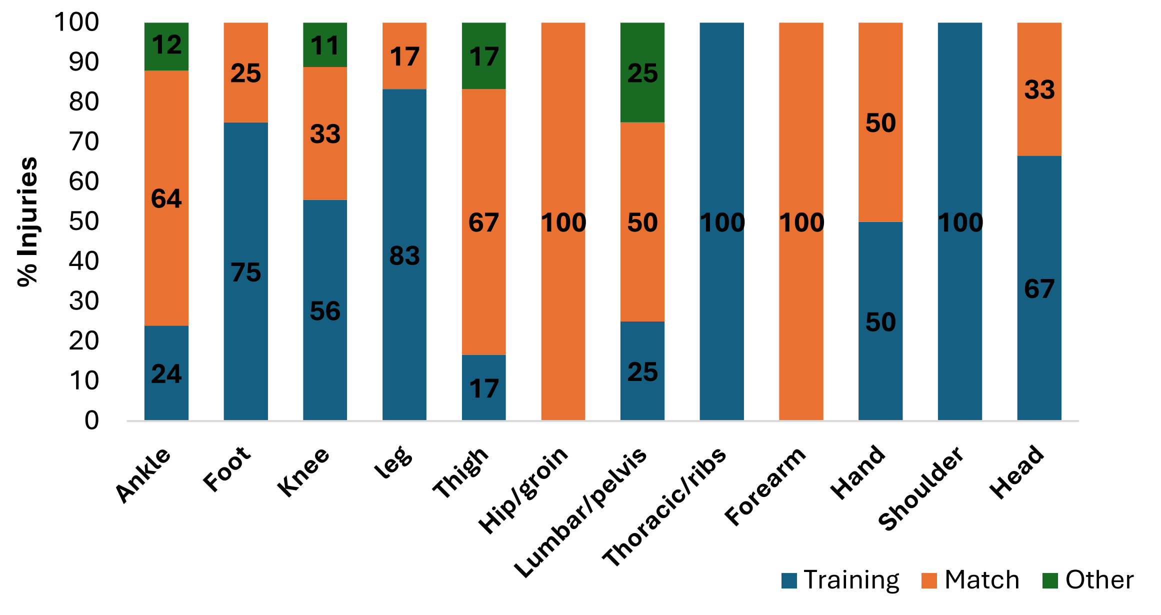
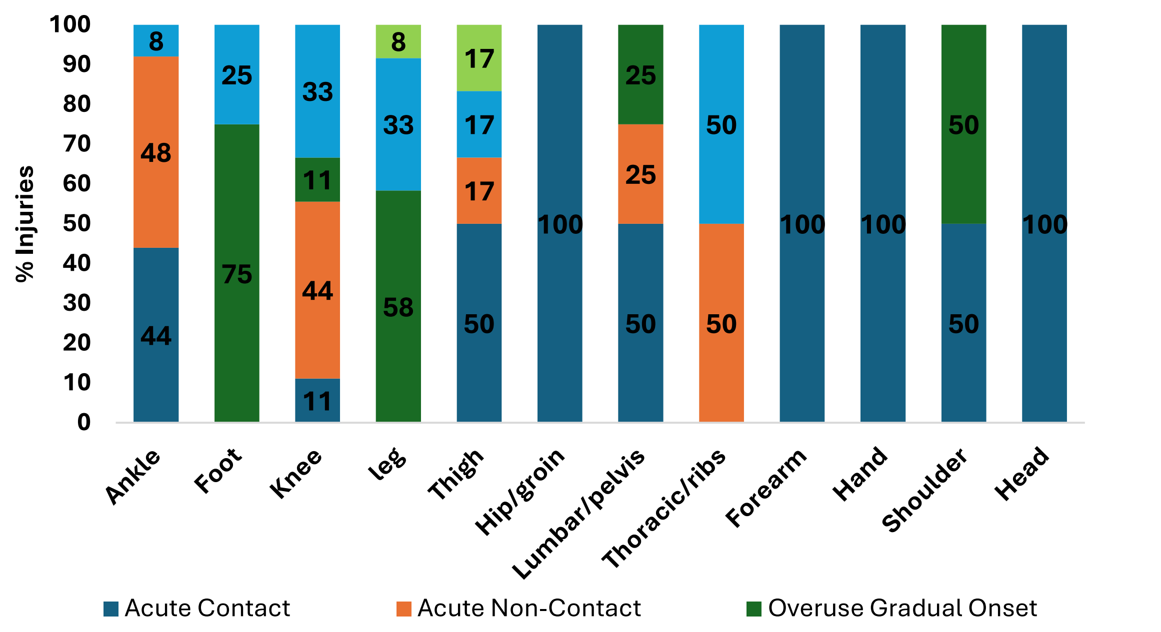


Figure 14: Site of Injuries and Mode



Type of Injuries

Table 1 shows the number and percentage type of injuries sustained at each injury site with the most frequent injuries highlighted. By far the most frequent injury type was ankle ligament sprains (30%, n= 22) which typically involved 1 or more of the lateral ligaments. A further 2 ligament injuries (3%) occurred at the knee involving the anterior cruciate ligament

Table 1: Type of Injuries

Type of Injury	Total Number (%) Injuries at each site											
	Ankle	Foot	Knee	Leg	Thigh	Hip/groin	Lumbar/ pelvis	Thoracic/ ribs	Forearm	Hand	Shoulder	Head
Concussion	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	**5 (7)**
Fracture	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	1 (1)	0 (0)	0 (0)
Other bone injury	0 (0)	2 (3)	0 (0)	3 (4)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Ligament sprain/tear	**22 (30)**	0 (0)	2 (3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Muscle strain/tear	0 (0)	0 (0)	0 (0)	0 (0)	2 (3)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)
Muscular Tendon injury	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Contusion/haematoma	1 (1)	0 (0)	0 (0)	0 (0)	**4 (5)**	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	1 (1)
Tendinopathy	0 (0)	0 (0)	2 (3)	**7 (9)**	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Arthritis/synovitis/bursitis	0 (0)	0 (0)	1 (1)	1 (1)	0 (0)	0 (0)	**4 (5)**	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)
Fasciitis	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Impingement	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)
Abrasion/laceration/skin lesion	0 (0)	1 (1)	1 (1)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0(0)
Other	0 (0)	0 (0)	2 (3)	1 (1)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)

(ACL). The next most frequent injury was tendinopathy (9%, n=7) which typically occurred at the Achilles tendon. Injuries at the knee also included patella tendinopathy (3%, n=2). Concussion injuries at the head accounted for 7% (n=5) of the 74 new injuries. Additionally, 5% (n=4) of thigh injuries were contusions of the thigh muscles and 5% (n=4) of lumbar/pelvis injuries were facet joint arthropathy.

The recurrent injuries at the ankle included a ligament sprain and posterior ankle impingement. At the knee cases of patella tendinopathy and bakers' cysts recurred. Achilles tendinopathy and retrocalcaneal bursitis leg injuries and anterior glenohumeral impingement at the shoulder were further injuries that recurred during the 2021 VNSL competition.

Severity of Injuries

The total number of days that injuries at each site resulted in medical attention, restricted days, unavailable days and the overall impact duration are shown in Table 2. Medical attention days represent ongoing treatment with no impact on training or playing. Restricted days represent the number of days players are restricted from training and/or playing and unavailable days are those when players cannot participate in training or playing. The overall impact duration of injuries at each site is the combination of the restricted and unavailable days.

Injuries at the ankle resulted in the highest number of medical attention (706) and unavailable days (535). Knee injuries resulted in the highest number of restricted days and second highest unavailable days. Consequently, knee injuries caused the highest impact duration (836 days) compared to ankle injuries (780 days). Leg Injuries also resulted in a high number of medical attention days (624 days), but a lower number of restricted days and subsequent impact duration (63 days). Hand injuries also led to a higher number of medical attention days (336) but this did not translate to any time away from training or playing. Finally, forearm and head injuries resulted in an impact duration of 52 and 59 days, respectively. The total impact duration of all injuries, in the 7 VNSL teams during the 2021 season, was 1818 days.

Table 2: Impact of injuries at each site (days).

	Number of Days			
Injury Site	Medical Attention Days	Restricted Days	Unavailable Days	Impact Duration
Ankle	706	245	535	780
Foot	68	8	0	8
Knee	440	340	496	836
Leg	624	63	0	63
Thigh	79	4	4	8
Hip/groin	1	0	0	0
Lumbar/pelvis	131	5	0	5
Thoracic/ribs	2	0	5	5
Forearm	0	0	52	52
Hand	336	0	0	0
Shoulder	56	2	0	2
Head	38	20	39	59
Total days	**2481**	**687**	**1131**	**1818**

The 7 recurrent injuries mostly resulted in medical attention only; however a considerable number of medical attention days were dedicated to these injuries (890 days). Only 1 recurrent injury at the knee (Bakers cyst) led to unavailable days (74).

Table 3 presents the severity of injuries at each site based on the number of unavailable days. The majority of injuries (70%, n=52) across all sites were slight (0-1 days). 6 (8%) major injuries occurred at the ankle with a further 1 (1%) at the forearm, resulting in more than 28 days out of the sport. The most severe injuries were the 2 (3%) long-term injuries (>6 months) located at the knee.

Table 3: Injury severity

	Number (%) unavailable days						
Injury Site	Slight (0-1 days)	Minimal (2-3 days)	Mild (4-7 days)	Moderate (8-28 days)	Major (>28 days)	Long-term (>6 months)	Missing Data
Ankle	11 (15)	0 (0)	1 (1)	2 (3)	6 (8)	0 (0)	5 (7)
Foot	4 (5)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Knee	6 (8)	0 (0)	1 (1)	0 (0)	0 (0)	2 (3)	0 (0)
Leg	12 (16)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Thigh	5 (7)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)
Hip/groin	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lumbar/pelvis	4 (5)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Thoracic/ribs	1 (1)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)
Forearm	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)
Hand	2 (3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Shoulder	2 (3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Head	4 (5)	0 (0)	0 (0)	2 (3)	0 (0)	0 (0)	0 (0)
Total	**52 (70)**	**0 (0)**	**4 (5)**	**4 (5)**	**7 (10)**	**2 (3)**	**5 (7)**

The majority of recurrent injuries were slight with 6 (86%) injuries resulting in zero unavailable days. 1 injury was classified as major impacting the athlete for more than 28 days.

Summary

<u>Limitations:</u>

- It was agreed with England Netball that the focus of this research would be the 9 English-based teams competing in the VNSL competition. Following recruitment 7 of the 9 English teams agreed to take part in the study. Hence the findings represent 78% of the English teams in the league.
- There was a wide variation in the number of injuries reported across teams in the VNSL 2021. To ensure the accuracy of data for future analysis it is important to

ensure all Physiotherapists are clear regarding the definition of injury for the competition and the method of recording injuries.

- This was the first season the PDMS medical records system was used to collect injury data due to the cancellation of the 2020 season. The injury information collected by the system varies slightly from the data collected from the 2019 injury surveillance system. Thus, direct comparisons are not always possible with the 2019 findings.
- Training injury incidence rates were calculated based on average player exposure data. More accurate records of individual player training hours will enable increased accuracy of incidence rates. Use of player tracking devices to assess training load would facilitate more accurate data increasing the accuracy of incidence rates. This would also be beneficial for the assessment and modification of player training loads to help prevent injuries.

<u>Injury Surveillance Findings</u>

The main findings from the injury surveillance of the 2021 VNSL competition were:

- The baseline data revealed 31% of the 90 players, who consented to take part in the study, had suffered a least 1 previous major injury requiring surgery and/or at least 6 weeks out of the sport. Most of these injuries occurred at the lower limb (knee, ankle and foot), with 9% having previously suffered severe ACL injuries to one or both knees. The data also revealed only approximately one third of the players used ankle tape or braces as an injury preventative measure for training and matches. There was also considerable variation across the teams in terms of the number of players using taping and braces. In light of the high number of ankle injuries in the 2021 competition ankle tape or braces may be worth considering as a possible future preventative measure against ankle injuries.

  There were also 11 pre-existing injuries that were ongoing into the 2021 season. Most of the injuries were knee injuries (73%) and the majority were overuse injuries (64%).
- Injury incidence rates were calculated using training and playing exposure hours. The total number of new injuries in the 2021 VNSL season was 74 injuries. Six of these injuries occurred outside the competition, hence incidence rates were calculated from the 68 injuries occurring during VNSL pre-season training, and training or match play during the competition. As reported in 2019, a slightly higher number of injuries were reported in training (n=35) compared to matches (n=33). However, when incidence rates are calculated the greater training exposure hours identifies a lower injury incidence rate during training. The 33 match injuries equate to an injury incidence of

32.5 injuries per 1000 playing hours, while the 35 training injuries equates to 8.38 injuries per 1000 training hours. When training and playing exposure are combined the total 68 injuries equates to an incidence rate of 13.1 injuries per 1000 hours. Comparisons with data from previous seasons are difficult due to differences in surveillance methods and methods of calculation of incidence rates but still provide some indication of differences across competition seasons. The overall incidence rate of 13.1 injuries per 1000 playing and training exposure hours appears to be greater than the rates reported in previous seasons: 2019 5.15 injuries per 1000 exposure hours; 2016 9.08 injuries per 1000 exposure hours. It is possible that the higher injury incidence rate in the 2021 season may have partially resulted from the impact of the Covid-19 pandemic. In discussion with a VNSL team strength and conditioning coach it was suggested players may have been less active in the off-season with reduced gym access due to the lockdowns. This resulted in players starting pre-season with lower fitness levels and body compositions requiring a more basic start to pre-season training and gradual development than subsequent years. Furthermore, the change in the competition structure due to the pandemic, which condensed the schedule to 20 rounds, semi-finals and finals over 16 weeks may also have impacted the injury incidence rate. It was particularly noted that the "double-headers" with matches on consecutive days were especially intense making player recovery challenging.

- A total of 74 new injuries occurred in 40 players in 2021. Hence, 44% of players were injured with 56% of players experiencing no injuries. Most players (65%) experienced 1 new injury, with a maximum of 8 injuries reported in 1 player. In addition, 6 players experienced a total of 7 recurring injuries during the competition.
- During pre-season training 23 (31%) injuries were recorded compared to 51 (69%) during the in-season period. While the match and training injuries across the whole season (pre-season and in-season) were similar (n=33 and 35 respectively) a greater number of recurrent injuries occurred during matches (n=4, 43%). Most of the new injuries were acute (63%) with a higher rate of acute contact injuries (43%). The overuse injuries (34%) were a more even distribution of gradual onset (18%) and sudden onset (16%) injuries. As reported in 2019 the injury mode varied in matches compared to training. Possibly as a consequence of the varied training activities, an even distribution of acute (23%) and overuse (24%) training injuries were reported. In comparison the majority of match injuries were acute in nature (38%).
- The development of injuries per month showed a gradual increase in the number of injuries in the pre-season period. This was followed by a rapid increase in injuries

during the in-season from February (9%) to March (19%) and April (20%) followed by a decrease in May (16%) through to June (4%). This is similar to the findings in previous seasons which report more injuries in the first half of the playing season. Although it should be noted that the number of matches in each month varied slightly: February 18; March 20; April 24; May 26 and June 12.

- Players in the C position (39%) recorded the most injuries across the 2021 season followed by WD (20%) and GD (16%). Fewer injuries were recorded in the GA (5%) and WA (5%) positions. The C and WD positions have also been reported as experiencing a high frequency of injuries in the 2018 and 2019 seasons.
- As commonly reported in netball injury research the lower limb was the most frequent injury site in the 2021 competition (77%). Ankle injuries were most common (34%) followed by leg (16%) and knee injuries (12%). Most of the ankle injuries were sprains of the lateral ligaments and the majority of leg injuries were due to Achilles tendinopathy. A wider range of both acute and overuse knee injuries were reported. A small number of trunk and upper extremity injuries were reported but of most interest was the increased number of head injuries (8%, n=6). 5 of the head injuries were concussion with 1 facial contusion. This finding is uncommon in netball and the VNSL competition. 1 concussion was reported in the 2018 injury audit but no other concussions have been reported in recent seasons. Contact with another player was the reported cause of 4 concussions with contact with a static object the other cause. Although, this could be a unique finding in the 2021 season it is important to continue to monitor these injuries and their potential impact in future seasons.
- The site of injury influences both the activity and mode of injury. Ankle injuries were most common in matches (64%) and were mostly acute in nature, occurring via both contact (44%) and non-contact (48%) causes. Leg injuries in contrast occurred mainly in training (83%) and were a combination of overuse gradual onset (58%) and sudden onset (33%). Injuries at the Knee occurred more frequently in training (56%) with 33% in matches and were mostly acute non-contact (44%), or overuse sudden onset (33%) in nature. A further 11% of knee injuries occurred due to both acute contact and overuse gradual onset causes. The head injuries occurred mostly in training (67%) with 33% recorded in matches.
- The PDMS system identified the impact of injuries by recording the number of medical attention, restricted and unavailable days. The combined restricted and unavailable days identified the total impact duration. Despite the fewer knee injuries reported they resulted in the highest impact duration (836 days). While most knee injuries (n=6, 8%) were categorised as slight (0-1 days) and 1 mild (in their severity,

the 2 long-term (>6 months) ACL injuries contributed significantly to the overall impact duration. Ankle injuries were again mostly slight (0-1 days) (n=11, 15%) in their severity, but 2 injuries (3%) were moderate (8-28 days) and 6 (8%) were major (>28 days). The greater number of ankle injuries contributed to the highest number of medical attention and unavailable days and the overall second highest impact duration. The injuries experienced at the leg resulted in the second highest medical attention days (624) but considerably fewer restricted and unavailable days and thus a much lower overall impact duration (63 days). The 2 acute hand injuries although only slight (0-1 days) in severity and impact duration required a high number of medical attention days (336). The forearm and head injuries contributed to the number of restricted and unavailable days and hence overall impact duration (52 and 59 days respectively) of injuries in the competition.

- These findings suggest injuries at the ankle and knee, particularly acute ligament injuries, were the most impactful injuries in the VNSL 2021 competition. This continues to be a consistent finding reported in previous netball injury research, and VNSL injury audits. The number of concussions experienced at the head were a new finding in the competition and had the most impact of the non-lower limb injuries. Little netball injury research has assessed the impact of overuse injuries in the sport. In general, the overuse injuries in the 2021 competition, particularly Achilles tendinopathy at the leg; patella tendinopathy and Iliotibial band friction syndrome at the knee; metatarsal bone stress and plantar fasciitis in the foot, resulted in a lower number of restricted and unavailable days and thus a lower impact duration. However, these injuries contributed considerably to the number of medical attention days.

Recommendations

- Continued and consistent assessment of injuries in the VNSL competition will help to inform understanding of the injury issues in elite netball in the UK. To facilitate the accuracy of injury data all teams should be encouraged to regularly report player injuries during pre-season and the competition period. Appropriate training on the use of the PDMS system and clear guidelines regarding the definition of injuries for the competition will also help ensure the consistency and accuracy of injury recording across teams.
- Continued development of strategies to minimise the high number of acute ankle injuries and reduce the severity of knee injuries will help minimise the impact of these injuries on individual players, VNSL teams and the competition as a whole.
- The higher number of concussions in the VNSL 2021 competition warrants further

investigation in subsequent seasons to establish whether they are an increasing trend. Furthermore, guidelines to minimise the burden of such injuries on players should be followed.

- Further research assessing the risk factors and mechanisms of netball injuries, particularly at the ankle and knee, will help to inform targeted injury prevention strategies.