A Ten-Year Nationwide Review of Youth Field Hockey Injuries in New Zealand

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Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor used artificial intelligence tools or generative artificial intelligence tools (unless it is clearly stated, and referenced, along with the purpose of use), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

Amelia Watkin Ward

August 2025

Candidate Contribution of Co-authored Papers

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Abstract

Youth sport participation offers a range of physical, social, and psychological benefits, yet the associated injury burden remains an ongoing public health concern. To date, anecdotal concerns regarding increasing youth sport injury rates have not been confirmed with appropriate data. In New Zealand (NZ), field hockey (hockey) is a popular sport for youth and ranks fifth among team sports for injury insurance claims according to national data. However, unlike other popular youth sports (e.g. netball, football, rugby), it does not yet have a sport-specific injury prevention framework, despite evidence that such programmes effectively reduce injury risk. This thesis aimed to determine if injury rates in youth sport are increasing and to inform targeted youth hockey injury prevention strategies. It consists of a systematic review of lower quadrant injury incidence in youth team sports and an epidemiological analysis of lower extremity injuries in NZ youth hockey using national insurance data.

The systematic review synthesised evidence from 45 studies with data collected between 2013 and 2024 in youth aged 10–24 years. The eight team sports with the highest injury insurance claims in NZ were explored: rugby union, football, netball, basketball, field hockey, rugby league, touch rugby, and cricket. No consistent increase or decrease in injury incidence was observed over time across sports, although this was limited by considerable heterogeneity in data collection methods. However, sport-specific patterns emerged: over time injury rates increased in rugby union, fluctuated in football, remained stable in netball, and decreased in basketball. Injury location patterns varied by sport, with common injuries occurring in the knee and ankle in basketball, hip/groin/upper leg in football, and hip/groin/upper leg and knee in rugby union. Compared to other sports, more research is needed in netball, hockey, rugby league, and touch rugby.

The epidemiological study analysed 10 years of Accident Compensation Corporation (ACC) injury claim data for youth hockey players aged 10–24 years. Lower extremity injury rates significantly decreased over the 10-year period, with rates 35% lower in 2022/23 compared to 2013/14. Knee injuries were the most common and costly, followed by ankle and hip/upper leg/thigh injuries. Females had significantly higher knee and ankle injury rates than males, and injury rates and costs increased with age. Seasonal injury spikes were observed at the start of the season (May-June) and around tournament periods (August-September), particularly in 10–19-year-old players.

Together, these findings provide little evidence of an increase in youth sport injuries over the last 10 years. The evidence does support the need for age-, sex- and sport-specific injury prevention strategies in youth team sport. In youth hockey, prevention efforts should prioritise knee injuries, particularly in older youth players, and address seasonal risk periods through preparation and load management. The results also highlight the importance of consistent injury surveillance methodologies to enable meaningful comparisons across sports over time and better inform injury prevention efforts. This thesis provides a

strong foundation to inform the development of hockey-specific injury prevention strategies in NZ and contributes to broader efforts to reduce youth sport injury burden.

Chapter 1
Introduction and Rationale

Background

Participation in youth sport, centred on recreational and fun activities, offers many physical, social, and psychological benefits. For the purposes of this thesis, *youth* refers to individuals aged 10–24 years, with the upper age band reflecting the United Nations definition of youth (United Nations, n.d.). Recent data from a large New Zealand (NZ) study concluded that sport may offer additional wellbeing value for young people over and above other forms of physical activity (Wilson et al., 2022). However, injuries in youth sport and their associated public health burden are an ongoing concern due to the potential for both short- and long-term health consequences including reduced levels of physical activity, recurrent injury risk, and healthcare costs (Emery & Pasanen, 2019).

Sport is the leading cause of injury in adolescents across much of the world (Emery et al., 2015), and sport-related injuries are increasing in NZ (Accident Compensation Corporation [ACC], 2019). Sport-related injury claims from the Accident Compensation Corporation (ACC), NZ's no-fault national insurance system, increased across all age groups between 2008 and 2017, the most significant of which was a 60% increase in those aged 10–14 years old (ACC, 2019). This may be due to over exposure to organised sport, with evidence that sport specialisation and overtraining at a younger age may increase injury risk (Carder et al., 2020; Jayanthi et al., 2020). It has been suggested that early specialisation is an emerging trend in youth sport, alongside an evident reduction in recreational free play in NZ and globally since 2000 (McGowan et al., 2020). When recommended sport participation volume thresholds are exceeded, including hours per week, months per year, and the ratio between organised sport and recreational free play, there is a significantly increased likelihood of gradual onset injury for youth players across a range of sports (McGowan et al., 2020).

Overtraining (OT) is a process of increased training intensity or volume which can evolve into a state of short-term functional overreaching (FOR), extreme nonfunctional overreaching (NFOR), or OT syndrome. FOR is often used within training cycles to enhance performance, whereas NFOR occurs due to an imbalance between excessive overload and inadequate recovery, leading to performance reduction or plateau lasting for weeks or months (Meeusen et al., 2013). Seventeen percent of a group of youth team-sport players across a range of sports experienced NFOR or OT which was linked to frequent injury occurrence (Matos et al., 2011). Existing literature also highlights sport-specific modifiable risk factors associated with increased injury risk in youth sport; for example, in field hockey, higher volumes of games and reduced postural control have been linked to increased injury risk in youth players (Furlong & Rolle, 2018; Mason et al., 2021). Team sports are reportedly associated with the highest rates of injury and burden across all sports (Emery et al., 2015). These youth sport injuries have the potential to lead to reduced sport participation, increased post-traumatic osteoarthritis, obesity, and all-cause morbidity (Emery et al., 2015).

Injury prevention programmes have been shown to be effective in reducing injury risk and improving population health outcomes in team sports (Emery et al., 2015; Jimenez-Garcia et al., 2023; Ross et al., 2021). Epidemiological data is important to guide injury prevention, with high quality data from sports injury surveillance systems needed to design and evaluate injury prevention strategies (Ekegren et al., 2016). Sports injury prevention models including the Translating Research into Injury Prevention Practice (TRIPP) framework (Finch, 2006) provide a guide for injury prevention research to develop effective prevention strategies in response to sport injuries (Ross et al., 2021). The TRIPP framework is a six-stage approach, from injury surveillance through to real-world implementation of preventive measures, as shown in Figure 1. The first two stages focus on injury data gathering, highlighting the importance of obtaining high quality sport injury data to establish injury aetiology and mechanisms and inform prevention measures. These measures are then developed and evaluated under ideal conditions. The final two stages consider implementation and effectiveness in real-world contexts (Finch, 2006).

Figure 1

The Translating Research into Injury Prevention Practice (TRIPP) Framework for Research Leading to Real-World Sports Injury Prevention.

Note. Adapted from "A new framework for research leading to sports injury prevention," by C. Finch, 2006, *Journal of Science and Medicine in Sport, 9*(1), 4 (https://doi.org/10.1016/j.jsams.2006.02.009).

The International Olympic Committee recommends the adoption of standardised data collection methods to ensure consistency and accuracy within injury surveillance methods (Horne et al., 2024). Detailed understanding of sport injuries from surveillance data and robust research methodologies provides a strong evidence base for effective prevention programmes, and insight into their implementation context (Finch, 2006; Horne et al., 2024). However, true sports injury surveillance through ongoing systematic collection of data is rare due to a range of factors (Ekegren et al., 2016). Likewise, sport injury incidence is likely underestimated in epidemiological studies using data collected from emergency department visits, as half of all sport injuries are treated elsewhere (Ross et al., 2021). Injury surveillance systems within hospitals and emergency departments often provide data on more severe sport injuries but are less likely to obtain information regarding mild injury. Therefore, it has become the expectation to rely on club or organisational level sport injury surveillance systems to capture minor to moderate injury data. An example of this is seen in competition data, such as from a tournament, which captures a broader range of injuries and can often provide a more accurate insight into the player injuries obtained when physical, emotional, and cognitive demand might be at its highest (Ekegren et al., 2016). Within sport, most surveillance systems have been identified in elite and professional sport, whereas a shortage of ongoing injury surveillance data exists in community and amateur sport settings. When addressed, this wider range of sport settings will enable improved monitoring of injury trends and strategy development (Ekegren et al., 2016). In NZ, detailed epidemiological injury data is available from ACC through its injury claims. As people qualify for cover following acute accidental injuries and there is no disincentive for making claims, injury cover is easily accessed through any ACC recognised, registered health professional (King, Hume, Hardaker, Pearce, et al., 2019). By using injury data from national insurance databases such as ACC, a higher proportion of national sports injury data of ranging severities, sporting levels, age, and sexes is captured (Ross et al., 2021).

One of the top eight team sports leading to ACC injury claims is field hockey, with the fifth highest number of claims for 2022, 2023, and 2024 (ACC, 2024a, 2025a). Field hockey also has one of the highest sport-specific injury rates in team sports for females (Caine et al., 2008). The physical demands of the sport, including running and rapid directional changes, require strong dynamic stability and flexibility of the lower extremity to minimise injury risk, particularly to the knee and ankle during tackling and cutting manoeuvres (Torre & Papalia, 2022). In NZ, participation in field hockey has been generally increasing over the last decade, aside from during the Covid-19 pandemic (Hockey New Zealand, 2023). Of the top five sports by ACC claims in NZ, three have undertaken nationwide reviews to better understand injury rates and their changes over time, providing insights for the strategic development of injury prevention programmes in netball, football, and rugby union (Belcher et al., 2020; King et al., 2024; Quarrie et al., 2020). Alongside hockey, basketball is the other sport within the top five by ACC claims in NZ (ACC, 2024a). Basketball NZ has recently initiated a national injury prevention strategy partnered with ACC, with the objective of creating a nation-wide basketball-specific injury prevention programme based on the same ACC SportSmart programme as those developed in netball, football, rugby union, rugby league, and touch rugby in NZ (ACC, 2023, 2025b; Basketball New Zealand, n.d.). While Hockey NZ has implemented some injury mitigation strategies over time, there is currently no formal hockey-specific injury prevention programme equivalent to those in other popular team sports with high levels of injury claims. Given the popularity of field hockey in NZ and the significant ACC injury claims, similar initiatives in field hockey are warranted.

Though there is concern that youth sport injuries are on the increase, this has not necessarily been confirmed with appropriately comparable data. Understanding the true increase in injury incidence will better outline the current and future socioeconomic strain and personal cost of youth injury, demonstrating the public health burden associated with youth sport injury (Emery et al., 2015). Although injury prevention programmes have been shown to be effective in reducing injury risk in team sport, no hockey-specific frameworks have been developed in NZ to date. To help inform future injury prevention strategies and reduce future injuries in youth hockey in NZ, a baseline understanding of injuries, rates, and changes should be established, as has been conducted in other common sports in NZ with high levels of injury.

Purpose of the thesis

Given the current limitations in the literature, this thesis has two key objectives:

1. To review existing evidence to determine how injury rates in youth team sports have changed between 2013 and 2024.
2. To review lower extremity injuries in youth field hockey in New Zealand using national insurance injury claim data over the 10-year period from 2013/14 to 2022/23.

The overall question of this thesis is “How have injuries in youth field hockey changed over the last 10 years and how can these trends help inform better injury prevention strategies?”

Thesis structure

This thesis is comprised of four chapters, presented in accordance with Auckland University of Technology’s Format Two.

Chapter 2 is a systematic review of the existing evidence on youth lower quadrant injury incidence rates in organised team sport from 2013 to 2024. It focuses on the eight sports with the most reported injuries in NZ, which annually account for approximately 40% of new sport injury insurance claims (ACC, 2024a, 2025a): rugby union, football, netball, basketball, hockey, rugby league, touch rugby, and cricket.

Chapter 3 is an epidemiological study of national insurance field hockey-related lower extremity injury claims in players aged 10–24y between 2013/14 and 2022/23 in NZ. It analyses hip/upper leg/thigh, knee, and ankle injury claims and costs by age and sex over time and explores seasonal lower extremity injury patterns in youth hockey players. This chapter aligns with Stage One of the TRIPP framework, providing the injury surveillance information required for the development, implementation, and evaluation of prevention measures (Finch, 2006).

Chapter 4 is an overall discussion which synthesises the key findings, discusses practical implications, and considers future research directions and how this may inform future injury prevention strategies.

Prelude to Chapter 2

Prior to exploring how injuries in youth field hockey have changed over the 10-year period from 2013/14 to 2022/23, it is first necessary to understand broader trends in youth team sport injuries over a similar timeframe. This chapter presents a systematic review of the existing literature on lower quadrant injury rates in organised youth team sports among players aged 10–24 years, from 2013 to 2024. The review focuses on eight sports that represent the highest number of team sport injury claims in New Zealand: rugby union, football, netball, basketball, field hockey, rugby league, touch rugby, and cricket.

Chapter 2

Injury Rates in Organised Youth Team Sport 2013–2024: A Systematic Review

Introduction

Sport participation provides a range of positive physical, social, and psychological benefits, particularly among youth (Emery & Pasanen, 2019; Wilson et al., 2022). However, sport is also the leading cause of injury in adolescents worldwide, and team sports have been associated with the highest rates of injury incidence and burden (Emery et al., 2015; Theisen et al., 2013). The highest sport injury and participation rates are in youth and young adults, and the lower extremity is the most commonly injured area, accounting for over 60% of injury burden across sports (Emery & Pasanen, 2019; Patel et al., 2024; Stephenson et al., 2021). Injury in youth sport and the associated public health burden remains a concern due to the potential immediate and long-term negative impacts on health and wellbeing, in addition to the associated costs (Emery & Pasanen, 2019; Emery et al., 2015).

New Zealand's (NZ) national no-fault insurance system, the Accident Compensation Corporation (ACC), reported sport-related injury claims increased between 2008 and 2017 across all age groups, with the greatest increase seen in youth (Accident Compensation Corporation [ACC], 2019). Eight sports are responsible for approximately 40% of all new sport injury claims and costs annually since 2013 in NZ including rugby union, football, netball, basketball, field hockey (hockey), rugby league, touch rugby, and cricket (ACC, 2024a, 2025a). Among these sports, the lower quadrant (lower extremity, pelvis, and lower back), is the most commonly injured in youth players (Carmont et al., 2022; Downs et al., 2021; François et al., 2022; Memmel et al., 2022; Pandey, 2015; Torre & Papalia, 2022).

Despite growing concern that youth sport injuries are increasing, there is a need for better evidence to confirm this. A more comprehensive understanding of any potential trends in youth sport injury incidence will provide better insight into the current and future socioeconomic strain of youth injury and its associated public health burden (Emery et al., 2015). Therefore, this systematic review aims to synthesise available epidemiological evidence on lower quadrant injury incidence rates in organised youth team sports between 2013 and 2024. By focusing on the eight team sports with the highest number of ACC injury claims (rugby union, football, netball, basketball, hockey, rugby league, touch rugby, and cricket), this review seeks to explore injury patterns to inform effective prevention strategies in NZ sports reporting the most injuries.

Methods

This systematic review followed the guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Page et al., 2021).

Search Strategy

The EBSCO Health electronic database (CINAHL Complete, MEDLINE, and SPORTDiscus) was searched on 1 October 2024. The search terms included: (youth* OR adolescen* OR teen* OR "young* adult*" OR child* OR kid) AND (injur*) AND (rate* OR incidence OR prevalen* OR epidemiolog*). Sport-specific search terms were then added: (soccer OR football) OR (netball) OR (basketball) OR (cricket) OR (hockey) OR (rugby). Search filters were then applied including English language only, peer reviewed articles with full text availability, published between 2000 and 2024, age filters (child 6–12 years, adolescent 13–18 years, young adults 19–24 years), and the results of the search must have detected keywords within the titles and abstracts. To ensure the inclusion of all relevant articles, citations from identified papers and excluded systematic reviews were also manually checked.

Eligibility Criteria

Eligible studies included those published in English which met the following inclusion criteria using a PEO format, as recommended for use in systematic reviews on aetiology and risk factors (Moola, 2020).
Population: Youth aged 10–24 years participating in organised team sports, reflecting the United Nations definition of youth (United Nations, n.d.).
Exposure: Participation in organised team sports with the highest injury rates by ACC claims in NZ (rugby union, football, netball, basketball, field hockey, rugby league, touch rugby, and cricket).
Outcome: Lower quadrant injury rates (including lower back, pelvis, and lower extremity).
Qualitative studies, review articles, commentaries, case reports, protocols, and conference proceedings were excluded from this review. Interventional studies were included, however only baseline or control group values were included for analysis to capture observational data rather than intervention impacts. Studies with a wider age range were included providing the data for the eligible age range could be extracted and independently reported.

Selection Process

All search results were imported into Rayyan, an online eligibility screening and reviewer blinding tool (Ouzzani et al., 2016). Duplicates were identified through an inbuilt automated detection software tool, screened and resolved by the primary author (AW). Compared to fully automated tools, it has been suggested that fewer errors occur when automation tools allow for a human checking process (Clark, 2023). The screening process consisted of several steps. Firstly, two authors (AW and CW) independently screened titles and abstracts to determine if they met eligibility. If eligibility could not be determined at the abstract level due to lack of information, the article was included for full text review alongside those that had been accepted. Secondly, the same two authors (AW and CW) independently reviewed the articles' full text against eligibility criteria. Studies that did not meet the eligibility criteria at either the title, abstract, or full text screening stage were excluded, with reason for exclusion agreed between authors. At each step of the screening process, the two authors met to resolve disagreements, and a third author (SB) was available when a consensus was not reached. During the selection process, it was decided that studies with data collection prior to 2013 would also be excluded. This decision was made due to the large number of initial search results potentially impacting an effective review. Also, data collected prior to 2013 was excluded due to the apparent sporadic nature of publications in the period 2000–2012. The authors believe the included dates balances the need for a period of time long enough to explore longitudinal injury patterns but short enough to offer comfortable comparison of historical sporting environments.

Data Extraction and Analysis

One author (AW) independently extracted injury incidence rate data from the included studies for lower quadrant body locations for youth aged 10–24 years. Alongside incidence rates, information regarding the denominator and injury definition used in each study was extracted. Other variables obtained included study design, participant characteristics, injury reporting method, data collection period, setting and location, and reported changes to injury rates over time. Two authors (CW and SB) verified the accuracy and completeness of the extracted data, which was then organised, adapted, and standardised as required to ensure comparability using Microsoft Excel (Microsoft Corporation, 2025). A meta-analysis was not conducted due to the heterogeneity of the findings, which resulted from the varying injury definitions and different denominators used for injury incidence rates across the investigated sports. For sports with sufficient comparable data from several studies using the same denominators and injury definitions, a visual representation of the results over time is provided. For all sports, a qualitative summary of the findings over time was conducted.

Critical Appraisal

One author (AW) assessed methodological quality and risk of bias (RoB) using JBI critical appraisal tools relevant to each study design. Due to the range of designs included in this review, several tools were used to ensure appropriate critical appraisal questions for each design. The JBI tools used included those for cohort studies (Moola, 2020), randomised controlled trials (RCTs) (Barker, Stone, Sears, Klugar, Tufanaru, et al., 2023), quasi-experimental designs (Barker et al., 2024), and analytical cross-sectional studies (Moola, 2020). An overall percentage of questions answered "yes" was calculated as an indication of methodological quality for each study, presented in a comparable way across tools with different numbers of questions. Previous systematic reviews that employed this method considered >80% of "yes" answers to be very high quality or a low risk of bias, 50–80% to be moderate risk of bias, and 20–50% to be high risk of bias (Siddiqui et al., 2021; Zhang et al., 2024). All eligible studies were included, with the percentage providing an indication of methodological quality and RoB. Common areas of RoB across studies were then summarised.

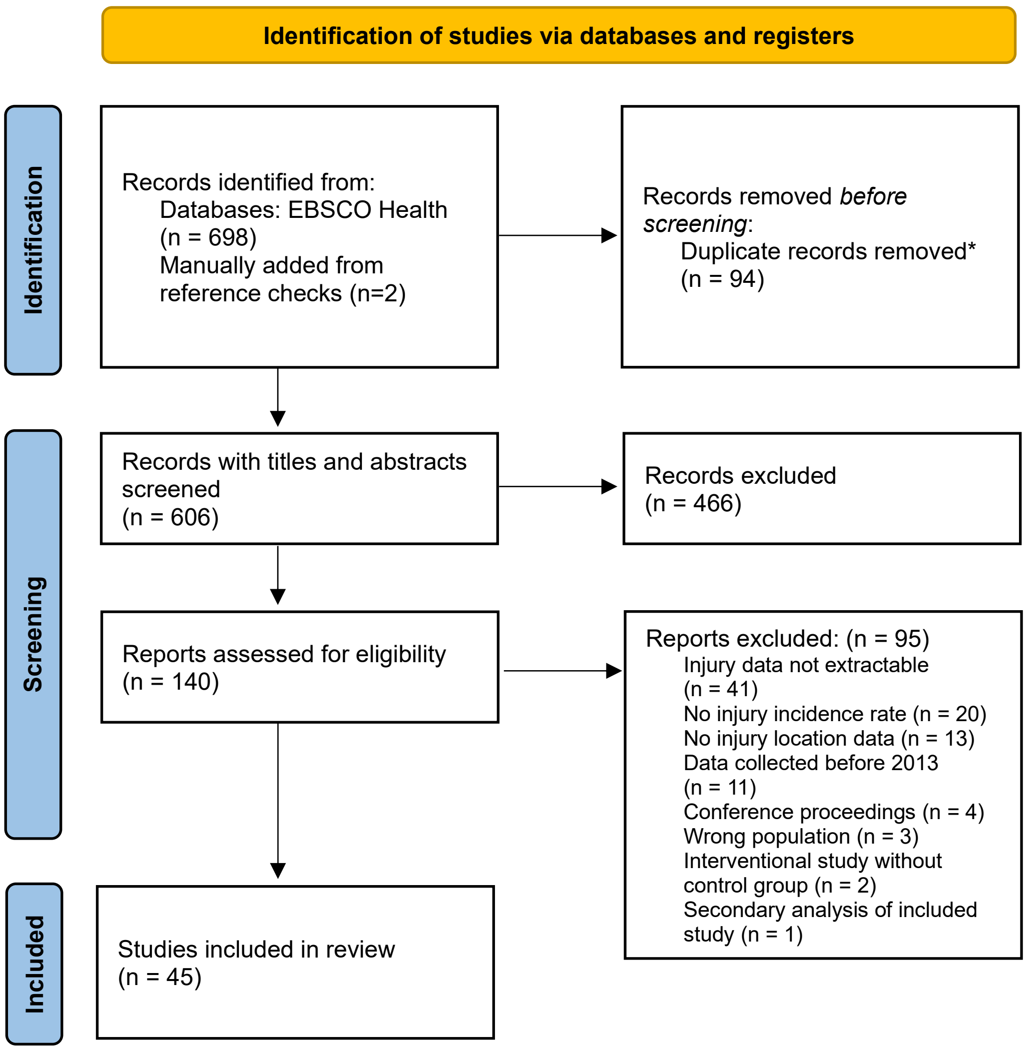
Results

Search Results

The initial database search returned 698 results, with 45 studies ultimately meeting inclusion. There were disagreements on six studies in the title and abstract stage and two in the full text stage of screening, all of which were excluded after discussion with the third author (SB). The PRISMA flow diagram outlining the screening process is shown in Figure 2.

Figure 2

PRISMA Flow Diagram



*Possible duplicates identified using Rayyan duplicate detection automation tool, then screened and resolved by a human.

Study Critical Appraisal

Table 1 summarises the outcomes from the methodological quality and RoB assessment using the JBI critical appraisal tools. The overall percentage shows that 32 (71%) of the reviewed studies are of very high quality with a low risk of bias, and the remaining 13 studies (29%) have a moderate risk of bias. Ten studies (22%) rated "yes" to all applicable questions. It is important to note that for the majority of studies with a cohort design, the first two questions were not applicable as there was often only one group of participants, all exposed to the given sport. Common areas of potential RoB in cohort studies were lack of clarity regarding the participants being free from injury at the beginning of the study, completeness of follow-up, and strategies to address incomplete follow-up. In RCT and quasi-experimental designs, areas of potential RoB were primarily related to the interventions; however, these are unlikely to have influenced the baseline or control group data extracted for this review. All analytical cross-sectional studies addressed all areas identified by the relevant JBI tool. The supplementary material contains the full sets of questions used for the methodological quality and RoB assessment, as shown in Appendix Table A1 (RCT design), Table A2 (Cohort design), Table A3 (Quasi-Experimental Design), and Table A4 (Analytical Cross-Sectional Design).

Table 1

JBI Critical Appraisal Summary

Study	Design	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	% of ✓ *
Darragi et al. (2024)	RCT	✓	?	✓	?	X	✓	✓ ?	✓	✓	✓	✓	✓	✓	73%
Hilska et al. (2021)	RCT	✓	✓	✓	X	X	✓	✓ X	✓ X	✓ ?	✓	✓ X	✓	✓	69%
Hislop et al. (2017)	RCT	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	100%
Obërtinca et al. (2024)	RCT	✓	✓	✓	?	X	✓	✓	✓	✓	✓	✓	✓	✓	85%
Zouita et al. (2016)	RCT	✓	?	✓	X	X	✓	?	✓	✓	?	✓	✓	✓	62%
Archbold et al. (2017)	Cohort	NA	NA	✓	✓	✓	?	✓	✓	✓	✓	✓			89%
Asgari et al. (2022)	Cohort	✓	✓	✓	✓	✓	✓	✓	✓	?	?	✓			82%
Astur et al. (2023)	Cohort	NA	NA	✓	✓	✓	?	✓	✓	✓	NA	✓			88%
Avedesian et al. (2022)	Cohort	NA	NA	✓	✓	✓	?	✓	✓	✓	✓	✓			89%
Bacon and Mauger (2017)	Cohort	NA	NA	✓	✓	✓	?	✓	✓	?	X	✓			67%
Barden et al. (2021)	Cohort	NA	NA	✓	✓	✓	?	✓	✓	✓	✓	✓			89%
Barden and Thain (2022)	Cohort	NA	NA	✓	✓	✓	?	✓	✓	?	?	✓			67%
Bittencourt et al. (2022)	Cohort	NA	NA	✓	✓	✓	?	✓	✓	✓	✓	✓			89%
Bowen et al. (2017)	Cohort	NA	NA	✓	✓	✓	?	✓	✓	X	X	✓			67%
Brow et al. (2021)	Cohort	NA	NA	✓	✓	✓	✓	✓	✓	✓	✓	✓			100%
Bult et al. (2018)	Cohort	NA	NA	✓	✓	✓	?	✓	✓	✓	✓	✓			89%
Cezarino et al. (2020)	Cohort	NA	NA	✓	✓	✓	?	✓	✓	✓	✓	✓			89%
Guitart et al. (2022)	Cohort	NA	NA	✓	✓	✓	?	✓	✓	?	?	✓			67%
Gupta et al. (2020)	Cohort	✓	NA	✓	✓	✓	?	✓	✓	✓	✓	✓			90%
Hartwig et al. (2019)	Cohort	NA	NA	✓	✓	✓	?	✓	✓	✓	✓	✓			89%
Jaber et al. (2022)	Cohort	NA	NA	✓	✓	✓	?	✓	✓	✓	NA	✓			88%
Keylock et al. (2022)	Cohort	NA	NA	✓	✓	✓	✓ X	✓	✓	✓	✓	✓			94%
Leppänen et al. (2021)	Cohort	✓	NA	✓	✓	✓	✓	✓	✓	✓	✓	✓			100%
Leung et al. (2017)	Cohort	NA	NA	✓	✓	✓	?	✓	✓	?	?	✓			67%
Light et al. (2021)	Cohort	NA	NA	✓	✓	✓	X	✓	✓	✓	✓	✓			89%
Martínez-Silván et al. (2023)	Cohort	NA	NA	✓	✓	✓	?	✓	✓	?	NA	✓			75%
Murray-Smith et al. (2023)	Cohort	NA	NA	✓	✓	✓	?	✓	✓	✓	NA	✓			88%
Nogueira et al. (2017)	Cohort	NA	NA	✓	✓	✓	?	✓	✓	✓	X	✓			78%
Olumide and Ajide (2016)	Cohort	NA	NA	✓	✓	✓	?	✓	✓	✓	✓	✓			89%
Owoeye, Ghali, et al. (2020)	Cohort	NA	NA	✓	✓	✓	✓	✓	✓	✓	✓	✓			100%

Study	Design	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	% of ✓ *
Robles-Palazón et al. (2022)	Cohort	NA	NA	✓	✓	✓	✗	✓	✓	✓	✓	✓			89%
Ruf et al. (2022)	Cohort	NA	NA	✓	✓	✓	?	✓	✓	✓	NA	✓			88%
Sewry et al. (2019)	Cohort	NA	NA	✓	✓	✓	?	✓	✓	?	?	✓			67%
Stojanović et al. (2024)	Cohort	NA	NA	✓	✓	✓	?	✓	✓	✓	NA	✓			88%
Thiebat et al. (2021)	Cohort	NA	NA	✓	✓	✓	?	✓	✓	?	?	✓			67%
Veith et al. (2024)	Cohort	NA	NA	✓	✓	✓	?	✓	✓	?	?	✓			67%
Wik et al. (2021)	Cohort	NA	NA	✓	✓	✓	?	✓	✓	✓	✓	✓			89%
Barboza et al. (2019)	Quasi-Experimental	✓	✓	✓	✓	✓	✓	✓	✓	✓					100%
Emery et al. (2022)	Quasi-Experimental	✓	✓	✓	✓	✓	✓	✓	✓	✓					100%
Sampson et al. (2021)	Quasi-Experimental	✓	✗	✓	✓	✓	✓	✓	✓	✓					89%
Sieland et al. (2020)	Quasi-Experimental	✓	✗	✓	✓	✓	✓	✓	✓	✓					89%
Belcher et al. (2020)	Analytical Cross-Sectional	✓	✓	✓	✓	✓	✓	✓	✓						100%
Black et al. (2021)	Analytical Cross-Sectional	✓	✓	✓	✓	✓	✓	✓	✓						100%
Cairo et al. (2022)	Analytical Cross-Sectional	✓	✓	✓	✓	✓	✓	✓	✓						100%
Sanz et al. (2020)	Analytical Cross-Sectional	✓	✓	✓	✓	✓	✓	✓	✓						100%

✓: Yes; ?: Unclear; ✗: No; NA: Not applicable * Rounded to nearest whole percentage. Questions answered 'NA' were removed from the denominator.

Note. **RCT** Q1–10: internal validity (Q1–3: selection and allocation; Q4–6: administration of intervention/exposure; Q7–9: assessment, detection and measurement of the outcome; Q10: participant retention); Q11–13: statistical conclusion validity.

Cohort Q1–10: internal validity (Q1: selection and allocation; Q2–3: classification of the exposure; Q4–5: confounding factors; Q6, Q8: temporal precedence; Q7: assessment, detection and measurement of the outcome; Q9–10: participant retention); Q11: statistical conclusion validity.

Quasi-Experimental Q1–8: internal validity (Q1: temporal precedence; Q2: selection and allocation; Q3: confounding factors; Q4: administration of intervention/exposure; Q5–7: assessment, detection and measurement of the outcome; Q8: participant retention); Q9: statistical conclusion validity.

Analytical Cross-Sectional Q1–7: internal validity (Q1: selection and allocation; Q2: comprehensiveness of reporting; Q3: classification of the exposure; Q4: assessment, detection and measurement of the outcome; Q5–6: confounding factors; Q7: assessment, detection and measurement of the outcome); Q8: statistical conclusion validity.

(Barker, Stone, Sears, Klugar, Leonardi-Bee, et al., 2023)

Study Characteristics

Participants. Sample sizes ranged from 16 to 503,564 participants across a range of study designs. The majority of studies included a male only sample (n=29, 64%), many of which were in football and rugby. Eight studies (18%) had a mix of males and females, mostly from basketball and football. Three studies (7%) looked specifically at females, predominantly from football. The remaining five studies (11%) were unclear regarding the sex of their participants. Most studies investigated youth teams of a variety of ages, with an overall age range of 10–24 years across the studies and an average age of 15.3 years.

Sports/Settings. Football was the most investigated sport (n=31, 69%), followed by basketball (n=8, 18%), rugby (n=8, 18%), hockey (n=2, 4%), netball (n=1, 2%), and cricket (n=1, 2%). The majority (n=28, 62%) of study settings were from club, academy, or representative team environments, whereas the school setting was investigated in nine studies (20%), and five studies (11%) investigated a combination of these environments. Finally, three (7%) studies were conducted in amateur or community sports teams. Aside from one study in football which collected data from a three-day tournament (Olumide & Ajide, 2016), all studies had data from one or more sport seasons, although season length varied across studies. Two studies on netball and football collated data from a 10-year period (Belcher et al., 2020; Gupta et al., 2020). Half of the included studies were undertaken in Europe (n=23, 51%), with over a third of those conducted in England. Six studies (13%) were undertaken in both North America and Australasia, four (9%) in Africa, and three (7%) in both South America and Asia.

Injury Definitions, Reporting Methods & Denominators. The most prevalent injury definition was time-loss injury (n=18, 40%). In basketball and rugby, a 24-hour time-loss injury definition was most common, in four and five studies respectively. The injury reporting method for 35 studies (78%) involved medical staff, approximately half of which utilised physiotherapists, and a quarter doctors or physicians. Self-reporting methods were either used in isolation or in combination with other methods in eight studies (18%). Alongside self-reporting methods, two of the eight studies used a team designate or coach to confirm injury details (Barboza et al., 2019; Emery et al., 2022), two involved medical staff further for injury diagnosis or verification (Hartwig et al., 2019; Olumide & Ajide, 2016), and two used both of these additional methods (Archbold et al., 2017; Owoeye, Ghali, et al., 2020). Two studies based on the same participant cohort used solely self-reporting methods through an anonymous online survey (Black et al., 2021; Cairo et al., 2022). The most common denominator used when calculating injury incidence rates was total exposure hours, used in 31 studies (69%), followed by match hours, used in 11 (24%). Other denominators included athlete exposures (AEs), players per year or season, squad season, and affiliated members.

Key study characteristics and findings are summarised in Table 2, grouped by sport. Injury incidence rates have been organised into the three most commonly reported lower quadrant injury locations: (i) hip/groin/upper leg, (ii) knee, and (iii) ankle. The term *upper leg* is used hereafter to collectively refer to the hip, groin, and upper leg injury locations. A full break down of results, including all reported injuries, is available in the supplementary material in Appendix Table A5.

Table 2

Key Characteristics and Findings

Study Location (Setting), Data Collection Period	**Population**	**Hip/Groin/Upper Leg Injury Rate**		**Knee Injury Rate**		**Ankle Injury Rate**	
Basketball							
Leppänen et al. (2021) Finland (junior regional league), May 2013–Apr 2014	n=130 12–21yrs, female & male	-		0.24/1000h (noncontact)		-	
				Female 0.37/1000h	Male 0.17/1000h		
				0.03/1000h (noncontact ACL)			
				Female 0.09/1000h	Male -		
Barden and Thain (2022) England (academy, national, & regional), 2013–2019	n=110 17.3 ± 0.9yrs, male	-		1.5/1000AEs		1.8/1000AEs	
				Match 1.2/1000AEs	Training 0.6/1000AEs	Match 5.4/1000AEs	Training 1.1/1000AEs
Barden et al. (2021) England (school), 2015–2019	n=843 (7 sports) 16–19yrs, female & male	3/1000mh		3/1000mh		24/1000mh	
Bittencourt et al. (2022) Brazil (club), 2016	n=271 14.2 ± 1.9yrs, male	-		1.59/1000h (patellar tendinopathy)		-	
Owoeye, Ghali, et al. (2020) Canada (school & club), 2016–2017	n=518 11–18yrs, female & male	0.27/1000h		6.9/1000h		5.49/1000h	
		Female 0.24/1000h	Male 0.27/1000h	Female 5.01/1000h	Male 7.49/1000h	Female 6.20/1000h	Male 5.01/1000h
Emery et al. (2022) Canda (school & club), 2016–2017	n=502 11–18yrs, female & male	-		11.8/1000h (knee & ankle)			
				Female 11.3/1000h		Male 12.1/1000h	
Black et al. (2021) Canada (school), Oct–Mar 2019	n=1,763 (multiple sports) 14–19yrs, female & male	0.59/100 players/year		3.93/100 players/year		7.27/100 players/year	
Stojanović et al. (2024) Serbia (regional league), Oct 2021–May 2022	n=218 17yrs ± 1.3yrs, male	-		0.07/1000AEs 0.04/1000h		0.14/1000AEs 0.09/1000h	
				Match 0.41/1000AEs 1.52/1000mh	Training 0.04/1000AEs 0.02/1000th	Match 1.62/1000AEs 6.06/1000mh	Training -
Cricket							
Keylock et al. (2022) England (professional academy, school, & club), 1x year, ~2020	n=22 14–17yrs, male bowlers	-		-		-	
Football							
Zouita et al. (2016) Tunisia (club), Sep–Apr (years unclear)	n=26 13–14yrs, male	-		-		0.54/1000h	
Avedesian et al. (2022) United States (school), 1x season (year unclear)	n=172 13–18yrs, female	2.47/1000AEs (lower extremity)					
Jaber et al. (2022) Germany (national & regional academy), 1x season (year unclear)	n=138 U12–U19, male	Match 1.79/1000mh	Training 0.18/1000th	Match 1.33/1000mh	Training 0.13/1000th	Match 1.39/1000mh	Training 0.14/1000th

Study	Population	Hip/Groin/Upper Leg Injury Rate	Knee Injury Rate	Ankle Injury Rate
Football (continued)				
Bacon and Mauger (2017) England (club), 2012–2014 (extracted 2013–2014)	n=23 U18–U21	4.08/1000h	2.40/1000h	3.60/1000h
Olumide and Ajide (2016) Nigeria (amateur), 3 days, Aug 2014	n=90 10–19yrs, male	40.1/1000mh	20.05/1000mh	6.68/1000mh
Bowen et al. (2017) England (premier league category one academy), 2013–2015	n=32 U18–U21	3.5/1000h Contact 1.1/1000h; Noncontact 2.4/1000h	1.7/1000h Contact 0.6/1000h; Noncontact 1.1/1000h	4.7/1000h (ankle/foot) Contact 2.6/1000h; Noncontact 2.1/1000h
Hilska et al. (2021) Finland (club), Jan–Jun 2015	n=730 U11–U14, female & male	0.40/1000h (contact)	0.39/1000h (noncontact) Female 0.40; Male 0.39	1.00/1000h (contact) 0.95/1000h (noncontact) Female 1.86; Male 0.72
Bult et al. (2018) Netherlands (club), 2013–2016	n=170 16–19yrs, male	2.81/1000h	1.38/1000h	1.63/1000h
Nogueira et al. (2017) Portugal (amateur), 6 months, 2015–2016	n=529 U17–U19, male	1.5/1000h	0.53/1000h	0.83/1000h
Gupta et al. (2020) United States (school), 2007–2017 (extracted 2013–2017)	n=100 schools High school aged, female & male	-	Female ACL 2014 0.19/1000AEs; Male ACL 2014 0.05/1000AEs Female ACL 2015 0.13/1000AEs; Male ACL 2015 0.03/1000AEs Female ACL 2016 0.10/1000AEs; Male ACL 2015 0.04/1000AEs Female ACL 2017 0.13/1000AEs; Male ACL 2017 0.02/1000AEs	-
Sieland et al. (2020) Germany (first division academy), 2015–2017	n=205 U12–U19, male	2.20/1000h (lower extremity)		
Sanz et al. (2020) Spain (regional academy), Oct 2016–Jun 2017	n=1,323 U9–U18 (extracted U11–U18), male	7.03/100 players/season U11 3.13; U13 4.17 U15 9.36; U18 16.93	-	-
Cezarino et al. (2020) Brazil (first division academy), Jan–Dec 2017	n=228 10–20yrs, male	0.7/1000h Match 3.12/1000mh; Training 0.52/1000th	0.43/1000h Match 1.49/1000mh; Training 0.35/1000th	0.36/1000h Match 1.93/1000mh; Training 0.25/1000th
Thiebat et al. (2021) Italy (club), 2015–2018	n=559 8–17yrs, U9–U17 (extracted U11, U16,U17)	1.91/1000h U11 0.78; U16 2.61; U17 2.31	0.77/1000h U11 0.37; U16 0.99; U17 0.93	1.09/1000h (ankle/foot) U11 0.37; U16 1.05; U17 1.86
Guitart et al. (2022) Spain (club), 2017–2018	n=41 U18–U19, male	2.68/1000h (lower extremity muscle) Time loss 1.34/1000h; Non-time loss 1.34/1000h		
Asgari et al. (2022) Iran (second division youth league), Jun–Oct (2018)	n=30 U12–U19, male	2.52/1000h	2.01/1000h	2.01/1000h
Barden et al. (2021) England (school), 2015–2019	n=843 (7 sports) 16–19yrs, female & male	Female 6/1000mh; Male 5/1000mh	Female 1/1000mh; Male 1/1000mh	Female 6/1000mh; Male 4/1000mh

Study	Population	Hip/Groin/Upper Leg Injury Rate		Knee Injury Rate		Ankle Injury Rate	
Football (continued)							
Light et al. (2021) England (premier league category one academy), 2015–2019	n=10 squads U9–U21 (extracted U11–U21), male	0.83/1000h		0.42/1000h		0.41/1000h	
		U11 0.19	U12 0.24	U11 0.14	U12 0.33	U11 0.14	U12 0.24
		U13 0.61	U14 1.35	U13 0.98	U14 0.47	U13 0.38	U14 0.19
		U15 0.87	U16 0.75	U15 0.45	U16 0.21	U15 0.24	U16 0.48
		U18 1.05	U21 1.51	U18 0.28	U21 0.70	U18 0.51	U21 0.99
Ruf et al. (2022) Germany (national & regional academy), 2016–2019	n=166 U14–U19, male	14.8/squad season		5.9/squad season		5.9/squad season	
		U14 17.4	U15 26.6	U14 8.0	U15 8.9	U14 7.6	U15 7.7
		U16 11.1	U17 12.2	U16 0.4	U17 0.4	U16 5.4	U17 5.2
		U19 9.1		U19 0.6		U19 4.3	
				0.4/squad season (ACL)			
Robles-Palazón et al. (2022) Spain (club), Sep 2017–Jun 2019	n=314 10–19yrs, male	1.4/1000h		0.6/1000h		0.4/1000h	
Brow et al. (2021) England (premier league category one academy), 2018–2019	n=25 16.5 ± 0.68yrs	-		10.03/1000h (knee & below)			
Cairo et al. (2022) Canada (school), 2018–2019	n=137 14–19yrs, female	3.6/100 players/year		10.8/100 players/year		8.6/100 players/year	
Astur et al. (2023) Brazil (club), 2018–2019	n=17,108 U13–U20, male	-		1.96/100 players/season (ACL 2018)		-	
				U13 0.30	U15 1.06		
				U17 2.82	U20 3.50		
				1.97/100 players/season (ACL 2019)			
				U13 0.22	U15 1.45		
				U17 2.17	U20 4.02		
Black et al. (2021) Canada (school), Oct 2018–Mar 2019	n=1,763 (multiple sports) 14–19yrs, female & male	2.79/100 players/year		5.26/100 players/year		7.43/100 players/year	
Sampson et al. (2021) Australia (A-league academy), 2019	n=55 U13–U15, male	4.25/1000h		4.26/1000h		1.25/1000h	
		Time loss 2.25	Medical attention 2.0	Time loss 1.5	Medical attention 2.76	Time loss 0.75	Medical attention 0.5
Wik et al. (2021) Qatar (national academy), 2016–2020	n=304 11–18yrs, male	4.7/1000h		1.6/1000h		1.7/1000h	
Martínez-Silván et al. (2023) Qatar (national academy), 2016–2020	n=591 11–19yrs,U13–U20, male	9/100 players/year		-		-	
Veith et al. (2024) Australia (national & regional academy), Nov 2017–Nov 2020	n=118 U13–U18, male	3.9/1000h		2.5/1000h		1.4/1000h	
		Time loss 2.2	Non-time loss 1.7	Time loss 1.2	Non-time loss 1.3	Time loss 0.9	Non-time loss 0.5
Obërtinca et al. (2024) Kosovo (club), 2021–2022	n=503 13–19yrs, male	1.31/1000h		0.68/1000h		0.64/1000h	
Darragi et al. (2024) Tunisia (national team), Dec 2023–Feb 2024	n=16 U15, female	2.39/1000h (lower body)					

Study	Population	Hip/Groin/Upper Leg Injury Rate	Knee Injury Rate	Ankle Injury Rate
Hockey				
Barboza et al. (2019) Netherlands (club), Oct 2016–Jun 2017	n=156 10–17yrs, female & male	3.65/1000h (lower extremity)		
Cairo et al. (2022) Canada (school), 2018–2019	n=20 14–19yrs, female	-	9.2/100 players/year	-
Netball				
Belcher et al. (2020) New Zealand (school, club, & representative), 2008–2017 (extracted 2014–2017)	n=503,564 278,946 (10–14yr) 144,186 (15–19yr) 80,432 (20–24yr)	-	2014/15 10-14y 26/1000m 15-19y 38/1000m 20-24y 39/1000m 2016/17 10-14y 26/1000m 15-19y 35/1000m 20-24y 37/1000m	2014/15 10-14y 48/1000m 15-19y 74/1000m 20-24y 72/1000m 2016/17 10-14y 46/1000m 15-19y 73/1000m 20-24y 63/1000m
Rugby				
Archbold et al. (2017) Ireland (school), Sep 2014–Mar 2015	n=825 16.8 ± 0.8yrs, male	3.61/1000mh	3.82/1000mh	3.07/1000mh
Hislop et al. (2017) England (school), Aug–Dec 2015	n=1,127 14–18yrs, male	7/1000h (lower extremity)		
Leung et al. (2017) Australia (school), 2015	n=480 10–18yrs, male	2.0/1000mh	3.6/1000mh	3.2/1000mh (ankle/foot)
Hartwig et al. (2019) Australia (school & interstate representative), 2016–2017	n=103 14–16yrs, male	3.34/1000h	1.11/1000h	2.45/1000h
Sewry et al. (2019) South Africa (school), Apr–Aug 2017	n=130 U16, male	13.9/1000h (lower extremity)		
Barden et al. (2021) England (school), 2015–2019	n=843 (7 sports) 16–19yrs, female & male	Male union 8/1000mh League 3/1000mh	Female union 9/1000mh Male union 7/1000mh	Female union 5/1000mh Male union 3/1000mh League 3/1000mh
Cairo et al. (2022) Canada (school), 2018–2019	n=59 14–19yrs, female	6.7/100 players/year	6.7/100 players/year	3.3/100 players/year
Murray-Smith et al. (2023) Australia (community), 2018, 2019, 2021	n=979 U13–U17, male	7.6/1000h (lower extremity) U13 5.3/1000h U14 8.3/1000h U15 7.6/1000h U16 22.5/1000h U17 6.5/1000h		

h=hours, mh=match hours, th=training hours, AE=athletic exposures, m=members

Study Findings

Basketball. Based on similar denominators and injury definitions across four studies (Barden et al., 2021; Barden & Thain, 2022; Leppänen et al., 2021; Stojanović et al., 2024) knee injury rates are lower in 2022 (0.04/1000h, 0.07/1000AEs, 1.52/1000mh) compared to 2014 (0.24/1000h) and 2019 (1.5/1000AEs, 3/1000mh). Similarly, based on three studies (Barden et al., 2021; Barden & Thain, 2022; Stojanović et al., 2024), ankle injury rates are lower in 2022 (0.14/1000AEs, 6.06/1000mh) compared to 2019 (1.8/1000AEs, 24/1000mh). Three studies investigated upper leg injury incidence; however, each used a different denominator so comparison over time was not appropriate.

Football. Figure 3 shows the results of 10 football studies reporting time-loss (TL) injuries by exposure hours for the upper leg, knee, and ankle.

Figure 3

Time-Loss Injury Rates per 1000 hours in Football

Based on TL injuries per exposure hours across nine studies, upper leg injury rates range from 0.7 to 4.7/1000h. The lowest rates are reported in 2016 (1.5/1000h, 2.81/1000h), 2017 (0.7/1000h), 2019 (0.83/1000h, 1.4/1000h, 2.25/1000h), and 2022 (1.31/1000h) while the highest rates are reported in 2015 (3.5/1000h), 2018 (2.52/1000h), and 2020 (4.7/1000h). For knee injuries, rates range from 0.42 to 1.7/1000h. Lower rates around 0.5/1000h are reported in 2016, 2017, 2019, and 2022, while higher rates around 1.5/1000h are reported in 2015, 2016, 2018, 2019, and 2020. Rates for ankle injuries based on eight studies range from 0.36 to 1.7/1000h, with rates at or below 0.75/1000h reported in 2017, 2019, and 2022 and rates above 0.75/1000h reported in 2016, 2018, and 2020.

Based on two studies (Barden et al., 2021; Cezarino et al., 2020) reporting TL injuries by match hours, upper leg and ankle injury rates were higher in 2019 (upper leg: 5.5/1000mh, ankle: 5/1000mh) compared to 2017 (upper leg: 3.12/1000mh, ankle: 1.93/1000mh). The reverse was reported for knee injuries with higher rates in 2017 (1.49/1000mh) compared to 2019 (1/1000mh).

Based on medical attention (MA) injuries per exposure hours reported in five studies (Bacon & Mauger, 2017; Hilska et al., 2021; Sampson et al., 2021; Thiebat et al., 2021; Veith et al., 2024), upper leg injury rates range from 1.9 to 4.08/1000h with the highest rate reported in 2014 and the lowest in 2018. Knee injury rates range from 0.76 to 2.76/1000mh with the highest rate reported in 2019 and the lowest in 2018. Ankle injury rates range from 0.5 to 3.6/1000h with the highest rate reported in 2014 and the lowest in 2019.

Rugby. Based on two studies (Archbold et al., 2017; Barden et al., 2021) using the same denominators and injury definitions, 24-hour TL rugby union injury rates in 2019 are higher for the upper leg (8/1000mh), knee (8/1000mh), and ankle (4/1000mh) compared to 2015 (upper leg: 3.61/1000mh, knee: 3.82/1000mh, ankle: 3.07/1000mh). Based on another two studies (Hislop et al., 2017; Sewry et al., 2019) investigating all 24-hour TL lower extremity injuries in rugby union, the injury rate is higher in 2017 (13.9/1000h) compared to 2015 (7/1000h).

Cricket, Hockey, & Netball. One study (Keylock et al., 2022) investigated cricket and reported an incidence rate of 27.3/100 players/year for lumbar bone stress injuries (LBSI) in adolescent male fast bowlers. This data is included in Appendix Table A5 but not in Table 2 as LBSI does not fit into the three most reported injury locations of upper leg, knee, and ankle. Two studies (Barboza et al., 2019; Cairo et al., 2022) reported hockey injury rates. In 2017, the lower extremity injury rate was 3.65/1000h (Barboza et al., 2019) and in 2019, the knee injury rate was 9.2/100 players/year (Cairo et al., 2022). One study (Belcher et al., 2020) investigated knee and ankle injury rates in netball from 2008-2017 using national injury claim data. Knee injury rates were similar in 2016/17 (10-14yr: 26/1000m, 15-19yr: 35/1000m, 20-24yr: 37/1000m) compared to 2014/15 (10-14yr: 26/1000m, 15-19yr: 38/1000m, 20-24yr: 39/1000m). Ankle injury rates were lower in 2016/17 (10-14yr: 46/1000m, 15-19yr: 73/1000m, 20-24yr: 63/1000m) compared to 2014/15 (10-14yr: 48/1000m, 15-19yr: 74/1000m, 20-24yr: 72/1000m).

Discussion

This systematic review investigated lower quadrant injury rates in organised youth team sports over the past 10 years. Priority was placed on sports considered high risk in NZ based on the sports with the highest number of ACC injury claims. In NZ in 2024, over 40% of all new sport injury claims were attributed to the eight team sports investigated in this review. Rugby union accounted for 30.3% of new injury claims within these sports, followed by football (24.7%), netball (12.2%), basketball (11.8%), hockey (6%), rugby league (5.2%), touch rugby (5%), and cricket (4.9%) (ACC, 2025a).

Overall, the key finding of the current review is that there is no clear pattern of injury rates increasing or decreasing over the past 10 years. Evidence for any change is clearly limited by the variation in data collection methods, making it difficult to examine overall trends in youth sport injuries over time. The heterogeneity of injury definitions, reporting methods, and analysis, including exposure data used as the injury rate denominator, is an agreed concern in existing sport injury epidemiology. These current inconsistencies commonly lead to discrepancies in injury incidence rates among existing youth sport injury research, making the comparison of epidemiological results challenging (Aarts et al., 2021; Patel et al., 2024; Prieto-González et al., 2021).

The majority of reviewed studies investigated youth football. There were very few studies investigating injuries in cricket, hockey, netball, or rugby league and no studies in touch rugby. When injury rates were examined by sport it was evident that common injury locations tend to differ between sports. For example, the lowest basketball injury rates were observed in the upper leg area, whereas this area tended to have the highest injury rates in football, indicating the importance of sport-specific injury prevention that focuses on the anatomical locations of common injuries. Multi-directional team sports have unique combinations of physical demands, such as larger jumping demands in basketball or higher volumes of running in football and hockey, which lead to different loading patterns and associated injuries (Taylor et al., 2017).

When considering youth populations, these physical demands are further challenged by the developmental changes of adolescence, including biomechanical, physiological, perceptual, and spatial changes that may impair movement coordination. The rapid bone growth and delayed muscle development associated with the adolescent growth spurt can disrupt sensory feedback and challenge neuromuscular control and coordination (Corso, 2018). This includes control of sport-specific skills, which may increase susceptibility to injury due to altered movement mechanics and load management (Patel et al., 2024). Sensorimotor function delays during adolescence have been shown to increase the risk of lower limb injuries, particularly those to the knee and ankle (McKay et al., 2016). Developmental changes do not occur uniformly across youth players; variations in maturation, particularly between sexes, can contribute to inconsistent neuromuscular control and injury risk (McKay et al., 2016; Parry et al., 2024). For example, adolescent females often experience disproportionately lesser gains in strength, power, and coordination compared to male contemporaries, resulting in a lag in neuromuscular control (Butler et al., 2022). Across sports, poor control of common movement demands can increase youth injury risk. However, motor skills, neuromuscular control, and sport-specific performance generally improve throughout adolescence (Patel et al., 2024).

Basketball

Both knee and ankle TL injury rates appear to reduce over the 10-year period in basketball, with lower rates across a range of denominators reported in 2014, 2019, and 2022. No comparisons over time were possible for the upper leg as all reported injury rates used different denominators. However, injury rates for the upper leg area were consistently lower than the knee and ankle across all reviewed basketball studies that compared injury locations. For the more common basketball injury locations, four studies found ankle injury rates to be higher than those for the knee (Barden et al., 2021; Barden & Thain, 2022; Black et al., 2021; Stojanović et al., 2024), and one study found the reverse to be true (Owoeye, Ghali, et al., 2020). The reported higher knee and ankle injury rates compared to the upper leg is consistent with previous systematic review findings that the most frequent youth basketball injuries occur in the knee and ankle (Aarts et al., 2021).

Factors likely contributing to higher knee and ankle injury rates in basketball include the physical demands of the game and the biomechanics involved such as jumping, landing, and directional changes, which constantly load the knee and ankle (Aksović et al., 2024). Basketball-specific risk factors for knee and ankle injuries other than game play in youth include poor balance, reduced ankle dorsiflexion range, and high hip abduction strength, particularly in females (Aarts et al., 2021). The current review reinforces previous findings, consistent with the injury risks associated with adolescent development, indicating that basketball-specific injury prevention strategies in youth should focus on the knee and ankle to have the most significant impact.

Football

Over the 10-year review period, a pattern is evident of lowering football injury rates between 2014 and 2017, higher rates from 2018 to 2020, and lower rates in 2022. This trend was observed across a range of denominators and injury definitions, including TL injuries by exposure hours for all three main injury locations, MA injuries by exposure hours for the upper leg and knee, and TL injuries by match hours for the upper leg and ankle. However, lower rates were reported over time for MA ankle injuries by exposure hours and TL knee injuries by match hours.

When interpreting the findings, it is important to consider potential societal impacts on the data over time. Prior to the current review period, the Fédération Internationale de Football Association (FIFA) 11+ injury prevention programme was developed in 2006 and promoted worldwide in 2009; however, implementation has remained challenging despite its efficacy in preventing football injuries (Bizzini & Dvorak, 2015). During the 10-year period of the current review, both the 'FIFA 11+ Referee' and 'FIFA 11+ Kids' versions of the programme were launched in 2013 and 2017 respectively (Bizzini & Dvorak, 2015; Franchina et al., 2023). The implementation and adherence of injury prevention programmes may have impacted injury rates over the last 10 years, although the uptake of the FIFA 11+ outside of research settings has been universally poor (Winstanley et al., 2023). The predominantly higher injury rates reported in 2020 coincide with the Covid-19 pandemic, which greatly disrupted organised sport. The cancellation, modification, or postponement of trainings and competitions to reduce virus transmission significantly impacted sport participation throughout 2020 and 2021 (Fitzgerald et al., 2021). Current evidence indicates that significantly higher injury rates occurred in various football populations following return to play after Covid-19 lockdowns, including among 13–18-year-old players, particularly in males (Yang et al., 2024), and in elite football leagues (Seshadri et al., 2021). This increase has been associated with physical deconditioning, including strength and neuromuscular deficits, resulting from prolonged periods of reduced training and competition. It has been suggested that return-to-play strategies following disruptive periods such as Covid-19 should be tailored to the individual athlete, considering sport-specific demands and intensity, to mitigate musculoskeletal injury risk (Ceglie et al., 2024).

Despite the fluctuation of injury rates reported over the last 10 years, the maximum change in rate indicates the magnitude of change over the review period. The variation of all TL injury rates by exposure hours is within 4/1000h for each injury location. Contrastingly, there appears to be a much greater level of variation in TL injury rates by match hours, as one reviewed study reported much higher TL injury rates by match hours in football in 2014 across the three main injury locations, particularly in the upper leg and knee (Olumide & Ajide, 2016). However, this was also the only reviewed study that used data from a multi-day tournament rather than one or more seasons, indicating that injury rates may be higher during concentrated periods of loading such as during a tournament. The high density of matches with short recovery times in between, and the tactical and technical demands associated with youth football tournaments lead to increased risk of injury, with higher injury incidence observed in tournaments and matches compared to training (Mandorino et al., 2023; Memmel et al., 2022; Patel et al., 2024). This is consistent across team sports where sudden spikes in acute load are associated with increased risk of non-contact injury, which make up a significant proportion of injuries in football (Griffin et al., 2020; Owoeye, VanderWey, et al., 2020). Across all youth sport, sudden increases in physical activity volume, intensity and duration are a consistent contributing factor to injury (Patel et al., 2024). A recent systematic review also suggested the existence of a positive association between cumulative workload and injury in youth team sport, particularly in football (Sniffen et al., 2022).

When considering injury locations, the upper leg area consistently had the highest injury rates among male players, typically followed by the ankle and then the knee. This aligns with previous systematic review findings that the most common injury location in male youth football players is the upper leg, followed by the ankle and knee (Pfirrmann et al., 2016). While the whole lower extremity is subjected to various types, amounts, and directions of forces in youth football, it has been suggested that adolescent football players develop a vulnerability to hip/groin/thigh injuries (Jones et al., 2020; Light et al., 2021; Memmel et al., 2022). This is due to several factors including incomplete muscle development while managing the large repetitive forces involved in football movements, and growth-related changes in limb-length, mass, and moments of inertia (Light et al., 2021). However, in the current review, the pattern of higher upper leg injury rates was less consistent in female and mixed-sex cohort studies, with more variation in common injury locations among female players. Of the four studies comparing injuries in females, two found the highest rates in the knee, one in the ankle, and one reported equal highest rate for the upper leg and ankle. Across female and male adolescent football players combined, it has previously been indicated that the most common lower extremity injury locations are the ankle and knee, closely followed by the upper leg/thigh (Faude et al., 2013; Memmel et al., 2022). Another reviewed study investigating ACL injuries over time in football found consistently higher rates in females compared to males (Gupta et al., 2020). This aligns with previous evidence which has shown ACL injuries to be particularly frequent in youth female football players, likely linked with the influence of hormones on the structure of connective tissue including ligaments, as well as gendered social expectations including those regarding strength and muscle development (Faude et al., 2013; Memmel et al., 2022; Parsons et al., 2021).

The findings of the current review indicate there has not been a clear continual increase or decrease in youth football injury rates over the last 10 years; rather, the rates have fluctuated over time. Consistent with existing literature, it is evident that upper leg injuries tend to have the highest injury rates compared to other injury locations in males, while injuries tend to be more spread across the lower extremity in female and mixed-sex cohorts, highlighting the need for continued injury prevention strategies that target the whole lower extremity.

Rugby

All the reviewed studies investigating rugby focused on rugby union, with one study also including rugby league (Barden et al., 2021). No study in the current review investigated touch rugby, a noncontact variant of conventional rugby. As the physical demands differ between rugby codes, particularly during match play, caution should be taken with generalisation of these findings across codes (Chow, 2020; Geeson-Brown et al., 2020; Naughton et al., 2021). Over the 10-year period of the current review, 24-hour TL injuries in rugby union appeared to increase for the upper leg, knee, ankle, and lower extremity overall, with higher injury rates reported across injury locations in 2017 and 2019 compared to 2015. The highest injury rates were observed in the upper leg and the knee, with rates either equal or higher in the knee.

This aligns with previous systematic review findings that hip/groin/thigh injuries are common across several youth sports including rugby, and that a lower extremity ligament sprain, particularly in the knee, is the most commonly reported lower extremity injury in adolescent rugby union and rugby league, likely due to the central component of tackling (Anderson et al., 2020; Carmont et al., 2022). Additionally, a NZ based epidemiological study using ACC data over a 13-year period reported the knee to have the highest mean claim rate of all lower extremity injury locations across most male and female rugby union players aged 7–

30 years (Quarrie et al., 2020). A similar epidemiological study investigating rugby league ACC injury claims over an eight-year period also found the knee to be the most common injury site (King, Hume, et al., 2009). The findings of the current review alongside existing literature highlight the consistently high rate of knee injuries in youth rugby. It also indicates that injuries to the upper leg occur at similar rates and therefore, lower quadrant injury prevention strategies in youth rugby should target both the knee and the upper leg areas.

Cricket, Hockey, & Netball

Few studies have evaluated lower quadrant injuries in youth cricket, hockey, and netball over the last 10 years. Therefore, it is difficult to evaluate changes in injury rates over time in these sports. However, the nature and content of the reviewed studies indicate the body locations where injuries are perhaps more common.

One study investigated lumbar bone stress injury (LBSI) in cricket players (Keylock et al., 2022), which has been previously described as the most prevalent injury in elite cricket, particularly among fast bowlers (Orchard, Kountouris, et al., 2016). Key risk factors for LBSI in youth fast bowlers include younger age, taller height, and faster bowling speed. Fast bowlers under the age of 22 are three to four times more likely to sustain bone stress injuries than older players, with LBSI risk increasing threefold for each year younger between 15 and 20 (Sims et al., 2021). This increased risk is associated with reduced bone mineral density during rapid adolescent growth. High bowling workloads may cause repetitive lumbar spine micro-trauma from cumulative shearing stress, potentially leading to LBSI and stress fracture (Sims et al., 2021; Soomro et al., 2018). In a NZ epidemiological study, male players aged 15–19 years accounted for the highest number of cricket related ACC injury claims from 2008 to 2018, with lumbosacral injuries representing over a third of their claims. Bowling was the leading cause of injury in male and female players aged 10–24 years, followed by batting and fielding. Lumbosacral injuries were most common in bowling and batting, especially in adolescents, while lower extremity injuries were most common in fielding, particularly to the knee (McLeod et al., 2023). This is consistent with earlier ACC data showing that male cricket players aged 10–24 years had the highest injury incidence, with lumbar injuries being among the most common (Walter et al., 2022). No studies in the current review evaluated youth female populations, aspects of cricket beyond bowling, or body locations beyond the lumbar spine, indicating areas for future research.

The two reviewed studies in field hockey highlight the significance of lower extremity injuries in the sport (Barboza et al., 2019; Cairo et al., 2022). This is consistent with previous systematic review findings that most field hockey injuries occur in the lower extremity, mainly to the ankle and knee in youth players (Barboza et al., 2018). Components of field hockey linked with injury include running and stepping manoeuvres, changes of direction, tackling and defending, blocking shots, and contact with the ball, stick, another player, or the ground (Barboza et al., 2018; Torre & Papalia, 2022). Good dynamic stability in the knee and ankle is required in field hockey players of all ages, particularly during cutting movements and tackling to minimise injury risk (Torre & Papalia, 2022).

The single study in netball focused on knee and ankle injuries as they are commonly described as the most prevalent injury locations in netball due to the associated risks of the repeated rapid decelerations, jumping and landing, and change of direction movements required in the sport (Belcher et al., 2020; Joseph et al., 2019). Landing with valgus knee collapse or limited knee flexion can increase lower extremity injury risk in netball; as can increased ground reaction force during landing due to growth related changes to joints, soft-tissue, bones, and neuromuscular control in youth players (Belcher et al., 2021). The reviewed study indicated that injury rates for the knee and ankle in youth netball players were similar or lower in 2016/17 compared to 2014/15.

More research should be conducted within netball, hockey, and cricket, which collectively accounted for 23% of new injury claims for the top eight team sport-related injuries, and over 9% of total new sport injury claims in NZ in 2024 (ACC, 2025a). Despite the paucity of research available on lower quadrant injuries across these three sports, the current review indicates a potential benefit for injury prevention in youth that is targeted towards the lower back in cricket, and the lower extremity in hockey and netball, particularly the knee and ankle.

Strengths & Limitations

A key strength of the current review is its breadth across a range of sports, populations, and study designs to provide a comprehensive overview of the status of injuries in youth team sports with the highest number of injury claims in NZ. However, this breadth also limited the ability to make comparisons over time due to the heterogeneity of the data and meant that a meta-analysis could not be conducted. Another strength is the robust systematic review process that was undertaken, with clear search and selection criteria and processes, enhancing the likelihood of capturing all relevant studies. A limitation of this review is the potential for publication bias as only studies that were published in English were eligible to be included; the exclusion of data presented in other languages may have influenced the findings.

A consideration when interpreting the findings of the current review is that the upper leg injury rates are the sum of three areas. This was done for clarity of reporting due to the range of injury locations recorded across the reviewed studies. Combining hip, groin, and upper leg locations allowed for the inclusion of as much data as possible for this injury area. However, this review consequently does not stipulate what proportion of all reported upper leg rates are attributable to each specific anatomical location. Where appropriate, the specific locations from each reviewed study are available in the supplementary material.

The most significant limitation of the current review is the inconsistent data collection across the reviewed studies, as the variation in injury definitions and injury rate denominators restricted comparisons over time. This inconsistency across studies highlights a need for consensus on injury surveillance methodology. Sport-specific consensus statements or similar have been published within football (Fuller et al., 2006), rugby union (Fuller et al., 2007), cricket (Orchard, Ranson, et al., 2016), and rugby league (King, Gabbett, et al., 2009), but have not been developed to date in basketball, netball, hockey, or touch rugby. The International Olympic Committee (IOC) published an updated sports-generic consensus statement in 2020 on methods for recording and reporting epidemiological data on injury and illness in sport (Bahr et al., 2020). It outlines several recommendations regarding injury definition, body area categories, assessment of exposure to calculate injury rates, and the expression of rates in an understandable way to effectively communicate injury risk. The IOC encourages the development of sport-specific consensus statements and the use of the Strengthening Reporting of Observational Studies in Epidemiology—Sport Injury and Illness Surveillance (STROBE-SIIS) checklist to support study design, protocol planning, and observation reporting, ensuring that injury surveillance research can be replicated, compared, and synthesised more easily (Bahr et al., 2020). The IOC recommendations aim to encourage the consistency in data collection, injury definitions, and research reporting that is needed within sport injury epidemiology (Bahr et al., 2020). Another more standardised approach to examine longitudinal trends may be to utilise national injury datasets, such as ACC injury claim data in NZ. While national injury datasets provide valuable large-scale and standardised surveillance, they do not fully align with IOC reporting standards and may therefore still present challenges for consistent injury reporting. Existing injury surveillance monitoring system methodologies are not consistently documented, and sport-related injuries can negatively impact player welfare at all participation levels in team sport (Sprouse et al., 2024). Therefore, there is an acknowledged need for the establishment of more universal surveillance systems in team sports to inform prevention efforts and improve player welfare and participation across levels, including youth players (Sprouse et al., 2024). Ultimately, adopting a consensus on injury surveillance in team sport would provide greater clarity in establishing the extent of sport injuries and changes over time, which is fundamental for injury prevention (Barboza et al., 2018).

Conclusion

Overall, lower quadrant injury rates in youth team sports appear to have been relatively stable over the last 10 years, with no clear increase or decrease over this time based on available evidence. The most commonly observed injury locations in each sport highlight potential areas for targeted injury prevention methods including the knee and ankle in basketball, the upper leg in football, and the upper leg and knee in rugby union. More research is needed in cricket, hockey, netball, rugby league, and touch rugby, as these sports are comparatively under-researched currently. The considerable heterogeneity in data collection methods makes comparisons over time difficult. Greater consensus on the methodology of sport injury surveillance, such as the wider adoption of IOC recommendations, would provide more clarity around injury trends in youth sport and facilitate a more comprehensive understanding to inform injury prevention strategies.

Prelude to Chapter 3

The systematic review presented in Chapter 2 identified no consistent pattern of increasing or decreasing lower quadrant injury rates across youth team sports between 2013 and 2024. However, it highlighted sport-specific trends, with injury rates appearing lower in basketball, higher in rugby union, fluctuating in football, and relatively stable in netball. The review also revealed the lack of evidence in hockey and supported the need for greater consensus in injury surveillance methodology.

Building on this broader understanding of injury trends in youth team sport, Chapter 3 focuses specifically on lower extremity injuries in youth field hockey in New Zealand. Using national insurance injury claim data from 2013/14 to 2022/23, this epidemiological study examines patterns in hip/upper leg/thigh, knee, and ankle injuries among players aged 10–24 years. The analysis explores injury incidence and associated costs by age and sex over time, and investigates seasonal trends in lower extremity injuries. This chapter aims to provide insight into injury risk in youth field hockey, considering differences across age groups, sexes, injury locations, and seasonal timing.

Chapter 3

Ten-Year Nationwide Review of Youth Field Hockey Lower Extremity Injuries in New Zealand

Introduction

Sport participation is a key contributor to a healthy lifestyle and is associated with important public health benefits for all ages, including promoting healthy growth and development, preventing chronic disease, and reducing stress (Emery & Pasanen, 2019). However, it also contributes significantly to injury burden, particularly among youth and young adults, who have high participation and injury rates across sports and face the greatest risk of sport-related musculoskeletal injury relative to other age groups (Emery & Pasanen, 2019; Stephenson et al., 2021). Among adolescents, sport is the leading cause of injury, with lower extremity (LE) injuries accounting for over 60% of the injury burden in youth sport (Emery et al., 2015).

Field hockey (hockey) is a popular team sport worldwide, played by both females and males in over 130 countries across recreational and professional levels (Torre & Papalia, 2022). Hockey participation among New Zealand (NZ) youth has increased annually over the last ten years, except for during the Covid-19 pandemic, with approximately 39,000 participants in 2013/14 and 44,000 participants in 2022/23 (Hockey NZ, 2023). The sport's physiological demands pose injury risks which may vary by demographics such as sex, age, and competition level. Research indicates that the LE is the most commonly injured area in hockey (Barboza et al., 2018). Effective flexibility and stability of the LE is essential to meet the physical demands of running and directional changes in hockey. In particular, good dynamic stability during cutting manoeuvres and tackling helps minimise injury risk, especially to the knee and ankle (Torre & Papalia, 2022). The International Hockey Federation (FIH) has reported acute injury incidences per 1000 player-match-hours of 86/1000 in youth girls, 53/1000 in youth boys, and 58/1000 in junior men, in comparison to 29/1000 in women, and 48/1000 in men; raising concern that acute injury incidence is higher in youth and junior players (International Hockey Federation [FIH], n.d.).

In NZ, insurance data from the Accident Compensation Corporation (ACC), NZ's national no-fault insurance system, show that hockey ranks fifth among team sports for injury claims (Accident Compensation Corporation [ACC], 2024a). National, multi-year reviews of injury epidemiology have been conducted in other popular NZ sports including netball (Belcher et al., 2020), football (soccer) (King et al., 2024), rugby union (King, Hume, Hardaker, Cummins, et al., 2019; Quarrie et al., 2020), rugby league (King, Hume, et al., 2009), and cricket (McLeod et al., 2023; Walter et al., 2022) to inform injury prevention programmes (IPPs). These studies highlight significant LE injury claims in several popular youth sports. In youth netball, ankle and knee injury claims increased between 2008 and 2017, with the largest increase observed in 10–19-year-old players and the overall highest injury rates and costs in 20–24-year-old players (Belcher et al., 2020). Injury claims also increased in football between 2010 and 2020, with the greatest number of claims reported among players aged 10–19 years, and the LE identified as the most frequently injured area (King et al., 2024). In rugby union, the LE accounted for over 37% of injury claims between 2005 and 2017, and the highest injury rates were seen in players aged 15–19 years, with injury rates increasing rapidly through adolescence (Quarrie et al., 2020). The knee was the most commonly reported injury site in rugby league between 1999 and 2007, and players aged 20–29 contributed the most to injury claims and costs (King, Hume, et al., 2009). Cricket injury incidence remained consistent or slightly decreased between 2005 and 2018, with youth players being the most injured age group. While lumbosacral injuries were generally more common overall, lower limb injuries, particularly to the knee, were frequently reported in batting and fielding (McLeod et al., 2023; Walter et al., 2022).

Since the establishment of ACC SportSmart in 1999, a nationwide sport performance and injury prevention framework in NZ, sport-specific IPPs have been adapted in collaboration with national sports organisations across five sports (ACC, n.d.): netball (NetballSmart), football (Fit4Football), rugby union (RugbySmart), rugby league (LeagueSmart), and touch rugby (TouchFit360) (ACC, 2025b). A sixth adaptation of SportSmart is currently being developed in basketball (BasketballSmart) (ACC, 2023). Each national review of sport injury epidemiology has endeavoured to identify key conditions, injury body sites, sex, and age group differentials that might guide IPP prevention efforts. These findings have informed the development of sport-specific injury prevention strategies, including the various IPPs adapted from the SportSmart framework. As an example, the NetballSmart programme has been delivered to around 132,000 players by approximately 8,460 coaches in NZ as of 2025, preventing up to 12,000 ACC injury claims (ACC, 2025c). However, despite hockey being responsible for the fifth highest number of team sport injury claims with ACC, no national longitudinal review of hockey injuries has been conducted in NZ to date. Given hockey's popularity and the substantial number of ACC injury claims, similar initiatives are warranted. A comprehensive understanding of injury types, rates, costs, and trends is essential to inform future injury prevention strategies.

Therefore, the aim of this study was to review ACC LE injury claims in youth hockey players aged 10–24 years from 2013 to 2023. The upper band of this age range reflects the United Nations definition of youth (United Nations, n.d.). Analysis focused on three injury sites: (i) hip/upper leg/thigh, (ii) knee, and (iii) ankle. The term *upper leg* is used hereafter to collectively refer to the hip, upper leg, and thigh injury locations. Trends were examined across time, age, sex, and seasonality to inform future injury prevention strategies tailored to youth hockey in NZ.

Methods

Youth hockey injury data were obtained from ACC and reported by injury site and monthly injury count for the three most common LE injury locations: (i) hip/upper leg/thigh (hereafter referred to as *upper leg*), (ii) knee, and (iii) ankle. Data spanned a 10-year period from 2013/14–2022/23. Injuries were defined as injury claims accepted by ACC where the accident sport was recorded as hockey and affected one of the three investigated injury locations. Injury data were reported by financial year (1 July to 30 June) and grouped by age, sex, and injury location, in alignment with ACC reporting practices. ACC's internal data protection and ethics team granted the request for release of the data sets (ACC, 2024b, 2024c). No further institutional ethics was deemed necessary as individual informed consent was not required due to the data being de-identified (without individual participant identification) or follow-up capability.

Annual injury rates per 1,000 affiliated players were calculated in Microsoft Excel (Microsoft Corporation, 2025) using injury count data from ACC and participation data from Hockey NZ. As the participation data were originally reported by calendar year and school year-based age groups, they were adapted to align with the financial year format (July–June) and the age group structure used in the ACC injury dataset. Age groups were defined as intermediate school (10–14y), high-school (15–19y), and young adult (20–24y).

Poisson regression analysis was conducted using JASP (JASP Team, 2024) to estimate incidence rate ratios with 95% confidence intervals (CIs). Age group, sex, injury location, and year were included as factors. The resulting regression coefficients were exponentiated using Microsoft Excel (Microsoft Corporation, 2025) to produce adjusted incidence rate ratios (aIRRs) with corresponding 95% CIs, indicating differences in injury rates between time points, sexes, age groups, and injury locations. Given the number of comparisons and subgroup analyses, a conservative *p* value threshold of .01 was applied for all analyses. Annual injury claim costs, including all accrued payments made up to 27 March 2024, were adjusted for inflation using the Consumer Price Index (CPI) published by the Reserve Bank of NZ, with all values standardised to Q1 2025 NZD (Reserve Bank of New Zealand, 2025).

A Shewhart control chart was used to identify seasonal patterns in injury counts for each age group over time. For this visual representation of seasonal trends, injury counts from all investigated injury locations and both recorded sexes were combined. Monthly injury counts recorded as fewer than four (n = 6) were entered as zero in the control chart analysis to maintain data reliability. The chart includes a mean control line (MCL) representing the average monthly injury count across all age groups and sexes over the 10-year period. The upper control limit (UCL) was calculated as three standard deviations (SDs) above the MCL, representing the upper threshold of expected variation. Injury counts exceeding the UCL would indicate special cause variation, reflecting extreme or unexpected injury counts beyond the normal seasonal pattern (Lloyd, 2019).

Results

Injury Rates

Injury rates for all three LE locations were significantly lower in 2022/23 compared to 2013/14 (aIRR = 0.65, 95% CI [0.62, 0.69], $p < .001$). Over the full 10-year period knee and ankle injury rates were significantly higher in females than in males (knee: aIRR = 1.25, 95% CI [1.20, 1.30], $p < .001$; ankle: aIRR = 1.42, 95% CI [1.36, 1.48], $p < .001$), and injury rates significantly increased with age (15-19y vs. 10-14y: aIRR = 2.09, 95% CI [2.03, 2.15], $p < .001$; 20-24y vs. 10-14y: aIRR = 3.28, 95% CI [3.17, 3.40], $p < .001$; 20-24y vs. 15-19y: aIRR = 1.58, 95% CI [1.52, 1.63], $p < .001$). The most common injury location was the knee, followed by the ankle, and then the upper leg (knee vs. upper leg: aIRR = 1.60, 95% CI [1.55, 1.65], $p < .001$; ankle vs. hip: aIRR = 1.36, 95% CI [1.31, 1.40], $p < .001$; ankle vs. knee: aIRR = 0.85, 95% CI [0.82, 0.87], $p < .001$). Full detailed comparison of injury rates by sex, age group, and injury location (reported by injury location and age group) are presented in Table 3.

Several interactions between sex, age group, and injury location over the 10-year period were explored within the Poisson regression analysis. While no differences in injury trends over time met the statistical significance threshold of $p < .01$, two interactions comparing injury locations over time had p values below .05. Specifically, ankle injury rates decreased by 16.2% more than upper leg injury rates (aIRR = 0.838, $p = .018$) and by 14.0% more than knee injury rates (aIRR = 0.860, $p = .022$) over the 10-year period. These interaction outcomes indicate that after controlling for age group and sex, ankle injuries showed a relatively greater decline in incidence compared to upper leg and knee injuries over time.

The highest mean injury rates across the 10-year period were observed in female knee injuries (10–14y, 16.9/1000; 15–19y, 32.8/1000; 20–24y, 44.8/1000), followed by female ankle injuries in younger players (10–14y, 16.6/1000; 15–19y, 28.7/1000), male upper leg injuries in the 20–24y group (39.6/1000), and male knee injuries across age groups (10–14y, 11.1/1000; 15–19y, 26.4/1000; 20–24y, 42.5/1000). Injury rates by age group, sex, and injury location over the full 10-year period from 2013/14 to 2022/23 are shown in Figure 4. A comparison of injury rates from 2013/14 and 2022/23 is presented in Table 4, alongside mean annual injury rates for the full 10-year period. A full breakdown of injury rate changes over time is available in Table A6 in the Appendix.

Table 3

a) Comparison of Injury Rates by Year, Sex, Age Group, and Injury Location (Reported by Injury Location)

	Hip/Upper Leg/Thigh	Knee	Ankle	Combined	Implication
2022/23 (2013/14)	0.69 * [0.62, 0.77]	0.69 * [0.63, 0.75]	0.60 * [0.54, 0.65]	0.65 * [0.62, 0.69]	2013/14 > 2022/23
Female (Male)	1.03 [0.98, 1.08]	1.25 * [1.20, 1.30]	1.42 * [1.36, 1.48]	1.24 * [1.21, 1.27]	Females > Males
15–19y (10–14y)	3.23 * [3.04, 3.44]	2.01 * [1.93, 2.10]	1.66 * [1.58, 1.74]	2.09 * [2.03, 2.15]	15–19y > 10–14y
20–24y (10–14y)	6.12 * [5.17, 6.56]	2.95 * [2.79, 3.12]	2.38 * [2.24, 2.53]	3.28 * [3.17, 3.40]	20–24y > 10–14y
20–24y (15–19y)	1.90 * [1.79, 2.01]	1.47 * [1.39, 1.55]	1.44 * [1.35, 1.53]	1.58 * [1.52, 1.63]	20–24y > 15–19y

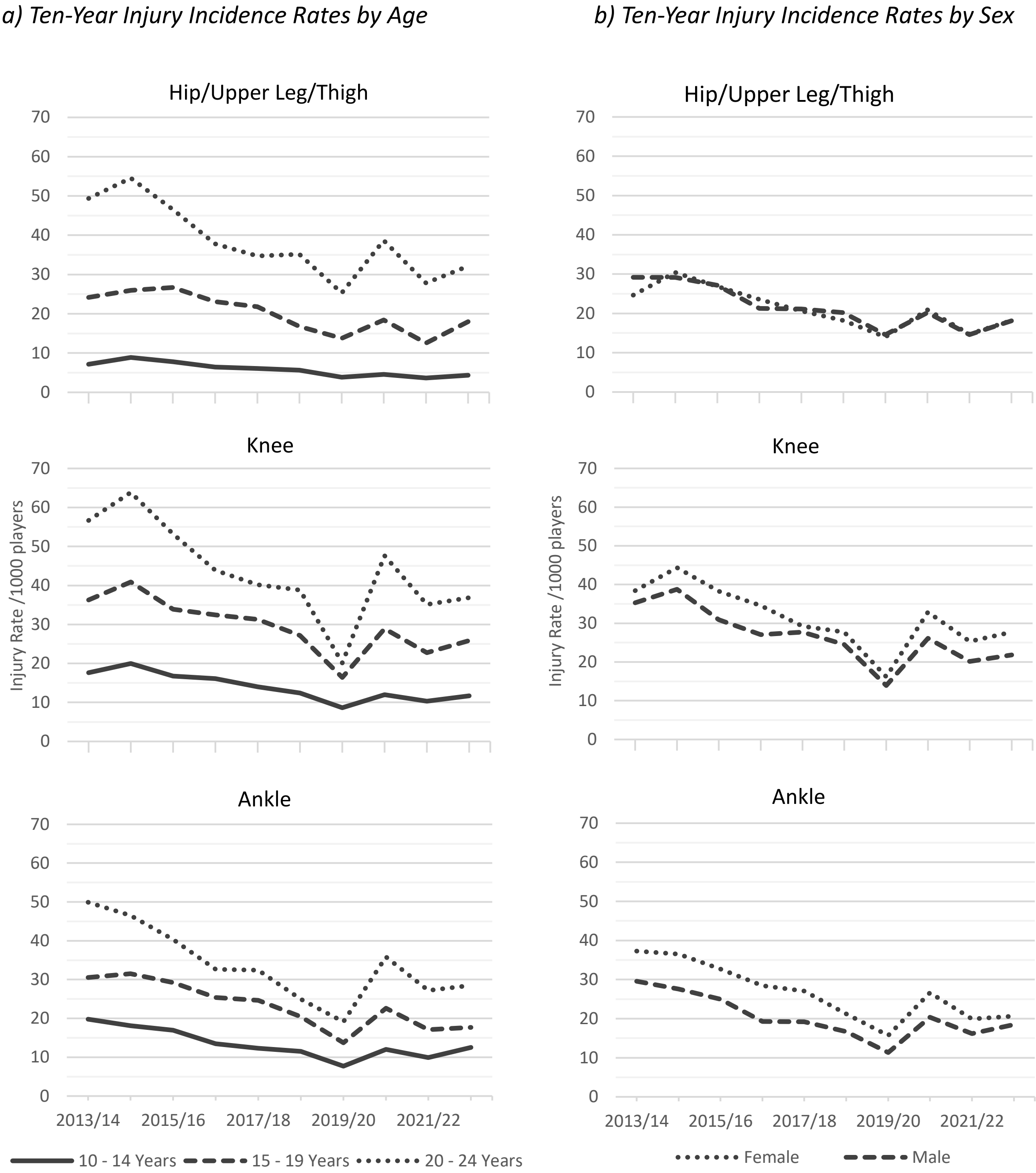
b) Comparison of Injury Rates by Year, Sex, Age Group, and Injury Location (Reported by Age Group)

	10–14y	15–19y	20–24y	Combined	Implication
2022/23 (2013/14)	0.64 * [0.58, 0.71]	0.67 * [0.62, 0.73]	0.63 * [0.56, 0.71]	0.65 * [0.62, 0.69]	2013/14 > 2022/23
Female (Male)	1.30 * [1.25, 1.36]	1.27 * [1.22, 1.31]	1.01 [0.96, 1.07]	1.24 * [1.21, 1.27]	Females > Males
Knee (Hip)	2.39 * [2.25, 2.53]	1.47 * [1.41, 1.54]	1.14 * [1.07, 1.22]	1.60 * [1.55, 1.65]	Knee > Hip
Ankle (Hip)	2.28 * [2.15, 2.43]	1.16 * [1.11, 1.22]	0.88 * [0.82, 0.95]	1.36 * [1.31, 1.40]	Ankle > Hip
Ankle (Knee)	0.96 [0.91, 1.00]	0.79 * [0.76, 0.82]	0.77 * [0.72, 0.83]	0.85 * [0.82, 0.87]	Knee > Ankle

Note. Adjusted incidence rate ratios [95% confidence intervals] with reference groups in brackets.

***** Indicates statistical significance $p < .01$.

Figure 4



a) Ten-Year Injury Incidence Rates by Age
b) Ten-Year Injury Incidence Rates by Sex
Hip/Upper Leg/Thigh
Knee
Ankle
Injury Rate /1000 players
70
60
50
40
30
20
10
0
2013/14
2015/16
2017/18
2019/20
2021/22
10 - 14 Years
15 - 19 Years
20 - 24 Years
Female
Male

Table 4

Annual Hockey Injury Rates 2013/14–2022/23

	2013/14 Injury Rate (/1000 players)	2022/23 Injury Rate (/1000 players)	10 Year Mean Annual Rate (/1000 players)
Hip/Upper Leg/Thigh			
10–14y Female	7.80	4.21	6.69
10–14y Male	6.51	4.43	4.98
15–19y Female	22.05	17.67	20.14
15–19y Male	26.32	18.31	20.09
20–24y Female	44.04	32.60	36.80
20–24y Male	54.75	31.64	39.62
Knee			
10–14y Female	20.02	13.24	16.86
10–14y Male	15.28	10.12	11.05
15–19y Female	38.35	28.36	32.77
15–19y Male	34.19	23.39	26.41
20–24y Female	56.90	41.63	44.78
20–24y Male	56.36	32.05	42.47
Ankle			
10–14y Female	24.01	14.96	16.60
10–14y Male	15.59	10.12	10.29
15–19y Female	37.39	19.09	28.70
15–19y Male	23.74	16.27	17.90
20–24y Female	50.47	27.89	34.56
20–24y Male	49.38	29.17	32.95

Injury Claim Costs

Annual Total Injury Claim Costs. Across all injury locations, sexes, and age groups, the total annual injury claim cost was 3.8% higher in 2022/23 compared to 2013/14. Upper leg and ankle annual total costs were lower at the end of the 10-year period across most age and sex groups, with a mean total cost reduction between 2013/14 and 2022/23 of 33.8% for upper leg injuries, and 13.2% for ankle injuries. In contrast, nearly all groups experienced higher annual knee injury claim costs in 2022/23 than in 2013/14, with an average total cost increase of 58.3%. For each injury location, sex, and age group, the total annual cost change between 2013/14 and 2022/23 ranged from -68.8% (10–14y female upper leg injuries) to +210.3% (20–24y female knee injuries).

The highest annual mean injury claims total costs across all age groups and sexes combined for the 10-year period were for knee injuries (NZ$199,690), followed by ankle (NZ$61,803), and upper leg injuries (NZ$46,383). When comparing age, sex, and injury location, the highest annual mean injury claim costs were for female knee injuries (10–14y, NZ$122,590; 15–19y, NZ$351,185; 20–24y, NZ$243,806), followed by male knee injuries in older age groups (15–19y, NZ$179,597; 20–24y, NZ$238,623), and female ankle injuries in the 10–14y group (NZ$74,974).

Cost per Injury Claim. For all injury locations, sexes, and age groups combined, the mean cost per injury claim was 42.1% higher in 2022/23 (NZ$966) compared to 2013/14 (NZ$586). The mean cost per claim increased for both knee and ankle injuries, with cost per knee claim increasing by 121.2% from NZ$928 in 2013/14 to NZ$2,054 in 2022/23, and cost per ankle claim increasing by 22.0% from NZ$395 in 2013/14 to NZ$482 in 2022/23. However, the mean cost per upper leg injury claim decreased by 17% from NZ$436 in 2013/14 to NZ$362 in 2022/23.

The mean cost per injury claim over the 10-year period was highest for knee injuries (NZ$1,160), followed by upper leg (NZ$432), and ankle injuries (NZ$425). Players aged 20–24y had the highest mean cost per injury claim (NZ$1,297), followed by those aged 15–19y (NZ$721), and 10–14y (NZ$389). On average, females had a higher cost per injury claim (NZ$741) than males (NZ$701).

Table 5 shows a comparison of annual total costs and cost per claim between 2013/14 and 2022/23, along with the mean annual values over the 10-year period. A full breakdown of annual total cost changes over time is available in Table A7 in the Appendix.

Table 5

Annual Hockey Injury Claim Costs 2013/14–2022/23 (NZ$)

	2013/14 Claim Costs		**2022/23 Claim Costs**		**10 Year Mean Claim Costs**	
	Annual Total	**Per Claim**	**Annual Total**	**Per Claim**	**Annual Total**	**Per Claim**
Hip/Upper Leg/Thigh						
10–14y Female	$33,172	$369	$10,348	$211	$27,385	$296
10–14y Male	$17,079	$271	$11,742	$255	$17,930	$292
15–19y Female	$47,888	$297	$48,775	$301	$83,512	$505
15–19y Male	$73,020	$397	$41,085	$285	$61,682	$400
20–24y Female	$47,259	$531	$29,157	$351	$39,660	$469
20–24y Male	$76,521	$750	$59,027	$767	$48,133	$558
Knee						
10–14y Female	$149,746	$648	$103,995	$675	$122,590	$529
10–14y Male	$66,040	$446	$85,246	$812	$62,342	$460
15–19y Female	$310,225	$1,108	$462,522	$1,779	$351,185	$1,309
15–19y Male	$148,191	$620	$156,893	$853	$179,597	$886
20–24y Female	$176,292	$1,533	$546,946	$5,160	$243,806	$2,374
20–24y Male	$127,465	$1,214	$237,313	$3,042	$238,623	$2,591
Ankle						
10–14y Female	$81,790	$295	$48,461	$279	$74,974	$333
10–14y Male	$34,503	$228	$29,869	$284	$34,271	$272
15–19y Female	$114,249	$418	$72,276	$413	$105,795	$453
15–19y Male	$53,547	$323	$63,813	$499	$56,364	$410
20–24y Female	$58,913	$578	$40,224	$567	$50,321	$635
20–24y Male	$48,501	$527	$60,252	$849	$49,094	$689

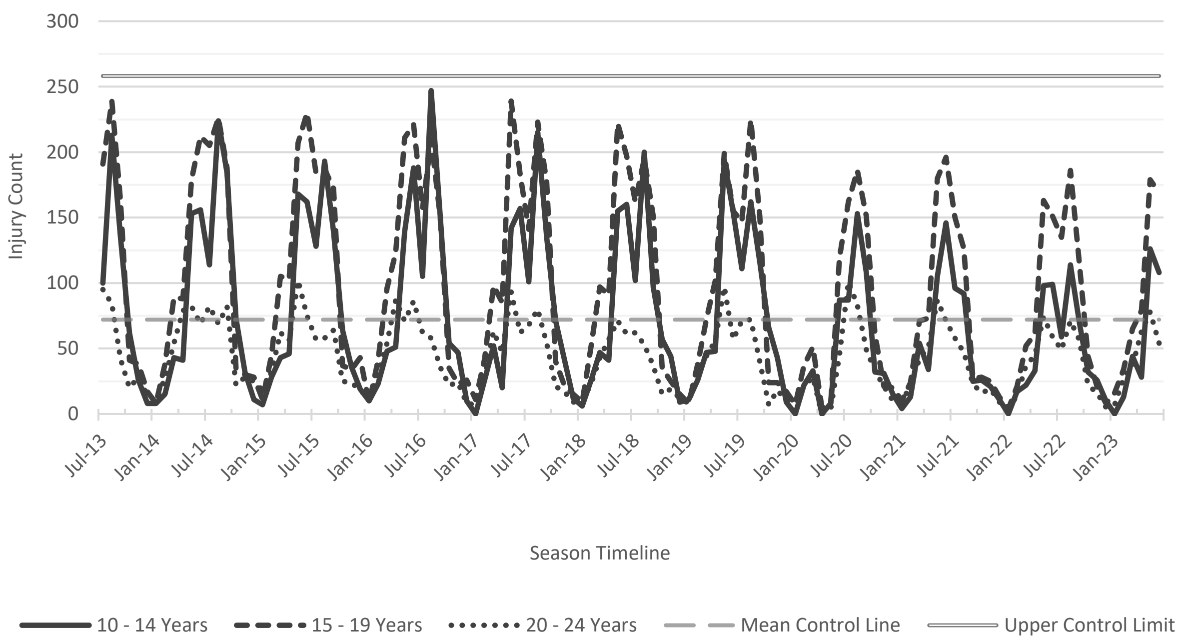
Seasonal Trends

The Shewhart control chart (Figure 5) shows consistent injury peaks in May/June, aligning with the start of the hockey season, and in August/September, corresponding with annual tournaments. An exception to this pattern occurred in 2020 and 2021, when trends were disrupted by the Covid-19 pandemic. Age specific patterns include more pronounced tournament spikes in the 10–14y group and higher start-of-season spikes in the 15–19y group. The 20–24y group exhibited a less distinct seasonal pattern.

No injury counts exceeded the upper control limit (UCL; 258) across the 10-year period. However, 21 data points between 2013 and 2021 were equal to or greater than the MCL +2SD, indicating periods of elevated injury counts that approached the threshold for special cause variation. These occurred in August for the 10–14y group, and between May and August for the 15–19y group. Notably, two of these spikes in the 15–19y group (August 2015 and May 2017, 239 injuries) were within 10% of the UCL, and one spike in the 10–14y group (August 2016, 247 injuries) was within 5% of the UCL.

Figure 5

Seasonal Injury Counts for Combined Sex and Locations



Discussion

Injury Rates

This large-scale retrospective epidemiological study examined comprehensive ACC injury data from 2013 to 2023 to investigate epidemiological trends in LE injuries in youth hockey in NZ. Across this period, all investigated LE injury rates in youth hockey players significantly decreased, with injury claim rates 35% lower in 2022/23 compared to 2013/14 in players aged 10–24y. This decline contrasts with broader ACC data showing increased sport-related injury claims across all sports between 2008 and 2017, particularly among 10–14-year-olds (ACC, 2019). Unlike these general trends, youth hockey has not followed the same trajectory. Similar longitudinal studies in other popular team sports in NZ have reported increasing injury rates in netball (Belcher et al., 2020) and football (King et al., 2024). However, as observed in hockey, injury incidence rates in cricket also declined between 2005 and 2016 (Walter et al., 2022).

Since 2013, several changes within hockey, youth sport more broadly, and injury management practices in NZ may have contributed to the observed decline in injury incidence. Hockey NZ has progressively restructured youth competitions and national tournament formats to better reflect development stages and the needs of youth. This included the adoption of small-sided formats, regional age-band events, and inclusive participation initiatives, which together may mitigate mismatches in player size and skill (Hockey New Zealand [Hockey NZ], 2021, 2022, 2023, 2024). In 2020, Hockey NZ adopted the "Balance is Better" framework developed by Sport NZ, alongside other major sport organisations. This initiative promotes age-appropriate development, long-term athlete wellbeing, and inclusive participation, aiming to address declining youth engagement and reduce injury risk (Hockey NZ, 2020). Hockey NZ has also continued to advocate for improved equipment and facility standards, including consistent use of mouthguards and shin guards, enhanced goalkeeper safety gear, and better turf maintenance (Hutchinson et al., 2016). ACC has continued to actively promote the use of IPPs in sport throughout the duration of this study period (Fulcher et al., 2018). Increased awareness and uptake of prevention frameworks such as ACC SportSmart may have contributed to reductions in injury rates among youth sport, despite the current absence of a hockey-specific IPP in NZ.

From an international perspective, secondary school hockey in NZ follows the FIH rules of hockey, which are adopted by Hockey NZ for use at this level (Hockey NZ, 2025b). The FIH rules are updated biennially and include provisions related to injured players, safe tackling, and protective equipment. The most recent update emphasised player safety by clarifying penalty procedures and reinforcing equipment standards (FIH, 2023). Additionally, the FIH adopted the quarter-based game format in 2014, which is now commonly used in NZ hockey from secondary school level and up. This replaced the traditional two 35-minute halves with four 15-minute quarters, in part to support improved player performance through more opportunities to re-hydrate and re-strategize (FIH, 2014).

The knee was consistently the most common LE injury location across all age groups and sexes. Among players aged 10–19y, the next most frequent injury site was the ankle, followed by the upper leg. For players aged 20–24y, upper leg injuries were more common than ankle injuries, although the knee remained the most frequently injured site. Previous systematic review findings in hockey also indicate that LE injuries predominantly impact the knee and ankle (Barboza et al., 2018). However, hip and thigh injuries were assessed separately in this systematic review, therefore limiting direct comparison of upper leg in relation to knee and ankle injuries.

Female players consistently exhibited the highest injury rates for knee and ankle injuries, particularly in the 10–19y age group. This pattern is reflected in broader injury trends, with anterior cruciate ligament (ACL) reconstruction incidence increasing disproportionately in females aged 15–19y between 2000 and 2016 in NZ, suggesting that young females have become a growing high-risk group for high-grade knee injuries (Sutherland et al., 2019). The higher rate of knee and ankle injuries in adolescent females compared to males may be explained by sex-specific developmental trajectories during adolescence. The adolescent growth spurt is associated with rapid bone growth and delayed muscle development, which can impair sensory feedback, neuromuscular control, and coordination (Corso, 2018). Females often experience a mismatch between gains in strength, power, and coordination compared to their male counterparts during adolescence, resulting in a neuromuscular control lag that increases LE injury risk, particularly for the knee and ankle (Butler et al., 2022; McKay et al., 2016). In addition to musculoskeletal and neurocognitive changes, hormonal changes through adolescence – including fluctuations in oestrogen levels – can influence ligament laxity and joint stability, further elevating the risk of LE injuries in adolescent females (McKay et al., 2016). No significant sex differences were observed for upper leg injury rates.

Injury rates significantly increased with age through youth, consistent with trends observed in other popular team sports in NZ such as netball and football (Belcher et al., 2020; King et al., 2024). This pattern may reflect the cumulative impact of developmental changes, as injury risk increases with both chronological age and pubertal development. While physical development predominantly occurs in early adolescence, cognitive development continues into early adulthood and is often not complete until around 25 years of age (McKay et al., 2016). As a result, older youth players may be physically mature but still developing cognitively, potentially increasing their vulnerability to injury due to suboptimal decision-making and risk assessment.

Furthermore, the demands of team sport increase with playing level, which likely contributes to the observed rise in injury rates with age (Tingelstad et al., 2023). These increasing demands include longer match durations, more frequent training sessions, and higher competitive intensity, particularly as players progress into higher leagues and representative competitions. In youth hockey, this demand increase is reflected in match structure progression. Intermediate-school-aged players typically play 6-aside games consisting of two 20-minute halves on a half-sized turf, whereas high-school-aged players consistently follow full FIH rules, playing 11-aside games of four 15-minute quarters on a full-sized turf (Auckland Hockey, 2023, 2025; FIH, 2023).

Injury Claim Costs

On average, inflation-adjusted injury claim costs for LE injuries increased by nearly 14% between 2013 and 2023. However, while direct comparisons between 2013/14 and 2022/23 showed a substantial increase in knee injury costs, reductions were observed in upper leg and ankle injury costs. Similar epidemiological studies using ACC cost data in NZ sport have reported increases in injury claim costs in football (2010–2020) (King et al., 2024), rugby league (1999–2007) (King, Hume, et al., 2009), and female rugby union (2013–2017) (King, Hume, Hardaker, Cummins, et al., 2019). These cost increases across various team sports likely reflect broader rises in healthcare service costs over time. In 2004, the inflation-adjusted annual total cost of treatment and rehabilitation to ACC was approximately NZ$1.8 billion, compared to around NZ$4.4 billion in 2024. Also in 2024, ACC spent NZ$1 billion to support recovery following sport and recreation injury, including treatment costs as well as other financial support such as weekly compensation for loss of income (ACC, 2025c).

Knee injuries consistently had the highest annual mean claim cost, generally followed by ankle and then upper leg injuries. An exception to this was observed in 15–19y males, where upper leg injuries had a higher mean annual cost than ankle injuries. Knee injuries also consistently had the highest mean cost per injury claim (NZ$1,160), followed by upper leg (NZ$432), and ankle (NZ$425) injuries. Evidence indicates the most reported LE injuries in hockey are knee and ankle sprains, and groin pain syndrome is also common. Within knee injuries, medial collateral ligament (MCL) injuries are common, with or without concurrent ACL injury (Torre & Papalia, 2022). In addition to initial diagnostic medical imaging, there is the possibility of the need for surgical reconstruction following a MCL or ACL tear alongside a lengthy rehabilitation process, with a graduated return to activity commonly taking six to twelve months (Torre & Papalia, 2022). This can therefore contribute to substantial costs following a knee injury compared to other LE injury locations, particularly where there is structural damage to a ligament.

In 10–14y and 15–19y players, females had a higher mean cost per injury claim for each investigated injury location. However, this was reversed in 20–24y players where males had higher injury costs per claim for all three injury locations. This may reflect the increased LE injury risk in 10–19y female players due to the musculoskeletal, neurocognitive, and hormonal changes experienced during adolescence, particularly impacting ligaments and joint stability in early- to mid-adolescence (McKay et al., 2016).

Most costs per injury claim increased with player age throughout youth. A similar pattern has been observed in netball (Belcher et al., 2020), football (King et al., 2024), and female rugby union (King, Hume, Hardaker, Cummins, et al., 2019). While higher claim costs may indicate injuries of a greater severity requiring more costly treatment, it also highlights the impact of income compensation on injury associated costs as the 20–24-year-old players are more likely to be employed compared to the younger players. An example of this is the average recovery cost of NZ$14,000 for an individual aged 20–29y following an ACL sport injury, with approximately 160 days off work (ACC, 2025c). Overall, these findings highlight the importance of targeted prevention strategies, particularly for high-cost injuries such as knee ligament damage, to reduce both individual burden and system-wide costs.

Seasonal Trends

As a winter sport, the NZ hockey season typically spans school terms two and three and the following holiday period, corresponding to late April or early May through to late September (Sport New Zealand, 2021). Tournaments begin in late June or early July with under 18 national tournaments, followed by intermediate and high-school aged tournaments in late August or early September near the end of the season (Hockey NZ, 2025a). Hockey player participation at secondary school level in NZ has been indicated as approximately five hours per week and seven months per year during a regular season (Rainey et al., 2024), indicating that participation often extends beyond the official season, possibly due to preseason training.

The injury spike observed in May and June corresponds to the early part of the hockey season and was particularly pronounced in players aged 15–19y. During this time, players are transitioning from summer sport participation or a period of reduced activity into trialling for school, club, and representative teams. This spike was followed by a decline in injury counts around July, particularly in 10–19y players, after the completion of trialling periods and the establishment of teams. Across youth team sports, sudden spikes in acute load through increased physical activity volume, intensity, and duration are associated with elevated risk of injury (Griffin et al., 2020; Patel et al., 2024). These findings highlight the need for improved hockey-specific physical preparation to reduce injury risk during trialling and early-season transitions.

The second injury spike observed in August and September aligns with the timing of annual intermediate and secondary school tournaments, and was more pronounced in 10–14y players, suggesting a potential under-preparedness or overloading during these events. Evidence from a range of youth team sports indicate a positive association between injury risk and cumulative load, such as that experienced during a tournament or over a full season (Sniffen et al., 2022). Therefore, in addition to utilising IPPs, load management strategies should also be considered as an injury prevention intervention in youth sport. Recreational (school and club) hockey players in NZ, who made up 52% of a sample of secondary school aged players, typically play one game per week and attend one tournament per year. In contrast, representative (regional and national) players average two games per week and two tournaments per year (Rainey et al., 2024). Some strategies have been implemented on a national level in youth sport that assist in the mitigation of overload related injury risk at sport events. Hockey tournaments in NZ typically run for a period of one week and are restricted to one or two games per team per day with at least four hours between consecutive matches (Hockey NZ, 2025a; 2025b, 2025c). Additionally, due to the concurrent scheduling of major intermediate and secondary school tournaments during the Association of Intermediate and Middle Schooling (AIMS) Games and School Sport NZ Winter Tournament Week, players are typically limited to participating in a single school-based sport tournament each year (AIMS Games, n.d.; School Sport New Zealand, n.d.). However, the August/September injury spike consistently present in youth hockey players indicates that further injury risk mitigation is required.

As the seasonal hockey injury counts did not exceed the UCL over the 10-year period, there is no indication of special cause variation showing unexpected injury counts beyond normal seasonal patterning. Although injury counts did not exceed the UCL, several periods of elevated injury counts approached this threshold, notably in August for 10–14y players and between May and August for 15–19y players. These findings highlight key periods within the season where injury prevention strategies should be prioritised to prevent injury counts from exceeding expected seasonal variation. Similar seasonal injury spikes around the beginning of the season and annual tournaments have been observed in youth Netball in NZ, particularly in 10–14y and 15–19y players. However, in contrast to hockey, both spikes tended to be more pronounced in 10–14y players and injury counts surpassed the UCL over several years in 10–19y players, suggesting excessive increases in injury count beyond the normal seasonal pattern (Belcher et al., 2020).

Implications for Practice

As knee injuries had both the highest mean injury rates and associated costs across age groups and sexes in youth hockey players, a resulting high injury and cost burden on these players and the NZ healthcare system is expected. Future injury prevention strategies targeting the knee in youth hockey players should therefore have the most significant impact at a player and national level. Evidence from other sports indicates that IPPs, particularly those incorporating neuromuscular warm-ups, have successfully reduced injuries, including those to the knee (Belcher et al., 2024; Sadigursky et al., 2017). Given that modifiable factors such as neuromuscular performance have been associated with LE injury risk in youth hockey players (Mason et al., 2021), these IPPs could be adapted for hockey-specific contexts to enhance their relevance, compliance, and overall efficacy (Fulcher et al., 2018). Both knee injury rates and costs increased with age, suggesting a need to encourage the continued use of injury prevention strategies through youth, especially in 20–24-year-old players.

Another key implication is the need for injury prevention strategies that focus on specific times within the hockey season each year. Seasonal peaks in injury claim counts indicate that targeted injury prevention may be most effective around the start of the season, particularly in 15–19y players, and around annual tournaments, particularly in 10–14y players. To help mitigate LE injury risk, it is important to consider load management strategies over the course of the season alongside the use of IPPs. In addition to existing measures including protective equipment and facility standards, and limiting game time at certain levels, other strategies may include the use of rolling substitutions, monitoring cumulative loads, and ensuring adequate recovery between sessions (Furlong & Rolle, 2018; Hockey New Zealand, 2025b, 2025c).

Future research directions may include investigating hockey injuries involving locations other than the LE, exploring injury mechanisms and severity, and evaluating the uptake and impact of any future hockey-specific IPP. Previous research on the perception and utilisation of recovery strategies in NZ youth hockey players provides insights into key barriers including time, resources, lack of knowledge, motivation, and fatigue (Rainey et al., 2024). These highlight important considerations for implementing injury prevention strategies in a youth hockey population. Examples include allocating time and space within training sessions and competitions for interventions such as exercise-based IPPs, and distributing educative injury prevention resources at school, club, and national levels. Further engagement with players and coaches throughout the development of a future hockey-specific IPP would also be valuable to determine what they deem important, as has been done in other sports such as futsal (Tomsovsky et al., 2021; Tomsovsky et al., 2020). This collaborative approach may help ensure that the IPP is contextually relevant and addresses practical barriers to implementation, therefore increasing its uptake and effectiveness.

Strengths & Limitations

A key strength of this study is the use of a comprehensive national dataset spanning 10 years, incorporating both injury claim and cost data to provide a more thorough understanding of the burden of LE injuries in youth hockey in NZ.

While the ACC system offers a strong source of epidemiological data, it has inherent limitations that should be acknowledged. Injury data are based on submitted ACC claims, which means that only acute injuries for which medical attention was sought and a claim was filed are included. Minor injuries where a player did not seek treatment or overuse injuries which fall outside ACC's claim criteria are therefore not included in the dataset. Additionally, only the primary injury site is recorded by ACC as the injury location for each claim in this dataset, excluding other locations in claims with multiple injuries. Furthermore, due to the nature of the available data, it was not possible to assess injury burden at the individual level, such as time loss, severity, or return to sport. These limitations may have collectively led to an underestimation of total hockey related LE injuries and their associated burden.

The annual injury claim cost data reflect all accrued payments made up to 27 March 2024 for injury claims lodged across the 10-year period. This has the potential to underestimate costs for more recent claims, as some expenses may not yet be fully accrued, particularly for long-term rehabilitation or compensation. However, the most significant expenses typically occur in the early stages following an injury, such as initial treatment, imaging, and any surgical interventions. The inclusion of claims up to 30 June 2023 allows for a nine-month window for cost accrual, mitigating this limitation to some extent.

The use of affiliated member data from Hockey NZ to calculate injury rates is another strength, enabling comparisons of injury risk across age groups, sexes, and years. However, these figures are annual participant estimates and were adapted to align with ACC's age group and year formatting. In the absence of detailed exposure data for youth hockey players across NZ, this approach of using participation data as the denominator for injury rates remains the most effective and practical method to provide an overview of the extent of hockey injuries in NZ.

Conclusion

Overall, the key finding of this large-scale epidemiological study is that LE injuries in youth hockey players significantly decreased between 2013 and 2023. The most common and costly injuries involved the knee, and knee and ankle injuries were more common in female players. Injuries and their associated costs increased with age through youth, and seasonal injury peaks occurred consistently at the start of the hockey season and around annual tournaments each year. These findings support the development of age- and sex-specific IPPs targeting the LE in youth hockey. Prevention strategies should focus on knee injuries, particularly in older youth players who experience the highest injury rates and costs. Additionally, facilitating pre-season preparation and optimal loading around tournaments may help to reduce injury risk in younger youth players. These findings provide a strong foundation for targeted injury prevention efforts and future IPP design, aiming to reduce both the personal and socioeconomic burden of LE injuries in NZ youth hockey.

Chapter 4

Discussion and Conclusions

The overall aim of this thesis was to investigate longitudinal trends and patterns in lower quadrant (LQ) injuries in youth team sports, focusing on changes in injury incidence between 2013 and 2024 and their implications for injury prevention. This was approached in two ways. Firstly, a systematic review synthesised existing evidence on youth LQ injury incidence rates across the eight team sports with the highest number of injury claims in New Zealand (NZ) (rugby union, football, netball, basketball, field hockey, rugby league, touch rugby, and cricket). Secondly, a nationwide epidemiological review analysed Accident Compensation Corporation (ACC) injury claim and cost data for youth field hockey in NZ, exploring trends over time in lower extremity (LE) injury rates, costs, and seasonal patterns. Both components focused on the 10–24-year-old age group, with the upper age band reflecting the United Nations definition of youth, which includes individuals up to 24 years old (United Nations, n.d.). By establishing a comprehensive understanding of current injury rates and trends, the findings from both the systematic review and hockey injury analysis provide insight into the burden of youth sport injuries and may inform future injury prevention strategies, particularly in youth hockey in NZ. The aim of this chapter is to synthesise the key findings from Chapters 2 and 3, further explore their practical implications, and consider future directions for injury surveillance and prevention in youth sport.

Synthesis of Key Findings

Injury Rates

The key finding of the systematic review was that there was no clear pattern of increasing or decreasing LQ injury rates across youth team sports between 2013 and 2024. However, some sport-specific trends were evident. Over the 10-year period, lower knee and ankle injury rates were reported in basketball, while higher LE injury rates were observed in rugby union. Injury rates fluctuated in football and remained similar or slightly lower in netball. In cricket, hockey, and rugby league, injury rate changes over time could not be evaluated due to limited data availability, and no data were available for touch rugby. The variation in data collection methods across the reviewed studies limited the ability to assess general trends across sports over time. The heterogeneity of injury definitions, reporting methods, and exposure measures observed in the systematic review is a well-documented challenge in sport injury epidemiology, often leading to discrepancies in reported injury incidence, and limiting the ability to compare results (Aarts et al., 2021; Patel et al., 2024; Prieto-González et al., 2021). This review contributes to the growing body of evidence supporting the need for greater consensus in injury surveillance methodology.

In contrast, the epidemiological analysis of youth hockey injuries in NZ found a significant decrease in LE injury incidence between 2013/14 and 2023/23, with the most notable reduction observed in ankle injuries. Therefore, the only sports with clearly lower injury incidence at the end of the 10-year period were hockey and basketball. All other investigated sports with comparable rates over time showed stable (netball), fluctuating (football), or increasing (rugby union) injury incidence.

Injury Location Patterns

When implementing injury prevention strategies in youth team sports, it is essential to consider the most frequently injured anatomical areas, which vary across sports, reflecting their distinct physical demands. Both the systematic review and the hockey injury analysis provided valuable insights into sport-specific injury patterns. For the purposes of this discussion, the term *upper leg* is used as a collective reference to the injury locations described as *hip/groin/upper leg* in Chapter 2 and *hip/upper leg/thigh* in Chapter 3. While these groupings differ slightly due to the nature of the data sources and reporting practices, they broadly represent injuries affecting the proximal region of the LE.

In basketball, the knee and ankle had the highest injury rates. Among male football players, the upper leg area was the most commonly injured, whereas in female football players, injuries were more evenly distributed across the LE. In rugby, the upper leg and knee were the most frequently injured areas. In the limited studies available for cricket, hockey, and netball, injury surveillance focused on the lower back (cricket), LE and knee (hockey), and knee and ankle (netball), reflecting areas that may commonly be affected in these sports.

The hockey injury analysis further highlighted that among LE injuries, the knee was the most common injury location overall, followed by the ankle in players aged 10–19y, and the upper leg in players aged 20–24y. These findings suggest that to have the greatest impact, injury prevention strategies should be tailored to the most affected areas in each sport: the knee in hockey, the knee and ankle in basketball, the upper leg in male football, the entire LE in female football, the upper leg and knee in rugby, the lower back in cricket, and the knee and ankle in netball.

Sex and Age Differences

The majority of studies included in the systematic review focused on male populations (64%), predominantly in football and rugby, while only 7% specifically investigated female populations, mostly in football. Mixed-sex cohorts were also used in 18% of studies, primarily in basketball and football. The remaining 11% of studies were unclear regarding the sex of their participants. The limited representation of female players combined with the heterogeneity of study designs restricted meaningful sex-based comparisons across sports. In football, which had the most available data, different injury patterns were evident between sexes: male players most commonly sustained upper leg injuries, whereas females and mixed-sex cohorts showed a broader distribution of LE injuries. One reviewed study comparing anterior cruciate ligament (ACL) injuries recorded consistently higher rates in female youth football players (Gupta et al., 2020).

In contrast, the nationwide hockey injury claim data enabled more robust sex-based comparisons. Females aged 10–24y showed significantly higher injury rates for both the knee and ankle compared to males. This trend was especially pronounced in 10–19y players, where females consistently had significantly higher injury rates than males for the upper leg, knee, and ankle combined. These findings align with existing literature suggesting that adolescent females are more susceptible to knee and ankle injuries, perhaps due to sex-specific developmental factors. Rapid bone growth paired with delayed muscle development during adolescence can impair neuromuscular control (Corso, 2018), and females often experience a mismatch in strength and coordination gains compared to males, increasing their vulnerability to LE injuries (Butler et al., 2022; McKay et al., 2016). Hormonal changes, such as fluctuations in oestrogen levels, may also increase ligament laxity and reduce joint stability, further elevating injury risk in adolescent females (McKay et al., 2016). These risk factors are reflected in broader injury trends, with a disproportionate increase in ACL reconstruction incidence among 15–19-year-old females in NZ between 2000 and 2016. This growing risk may be influenced by increased sport participation, musculoskeletal immaturity, and the higher risk of ACL injury per sporting exposure observed in females (Sutherland et al., 2019). Consideration should also be given to gendered environmental factors in sport, including disparities in access and participation, gendered training contexts, sociocultural expectations, and overall experiences and opportunities within sport. Evidence suggests that these extrinsic gender influences may impact intrinsic injury risk factors, such as biomechanical movement patterns and deficits in strength and neuromuscular control (Parsons et al., 2021).

Age also plays an important role in injury risk within youth sport. The reviewed studies included players ranging in age from 10–24y, with an average age of 15.3 years. Most studies did not separate results by age group and injury location within their youth populations, limiting age-based comparisons. However, one netball study found injury rates significantly increased with age in players aged 10–24y (Belcher et al., 2020), a trend also observed in the hockey injury analysis, which showed a significant rise in injury rates as age group increased from 10–14y to 15–19y to 20–24y. This pattern likely reflects both physical and cognitive developmental trajectories. Although most physical maturation occurs in early adolescence, cognitive development – particularly decision-making and risk assessment – continues into early adulthood and may not fully mature until around age 25 (McKay et al., 2016). This developmental gap means that older youth players, while physically capable of higher-intensity actions, may still lack fully developed cognitive skills to assess risk, potentially leading to sub-optimal decision making and a greater risk of injury. Additionally, the demands of team sport intensify with age and playing level. Higher-level youth players face longer matches, more frequent training, and greater competitive pressure, all of which likely also contribute to increased injury rates (Tingelstad et al., 2023).

Injury Costs

Although injury-related costs were not examined in the systematic review, their inclusion in the hockey injury analysis provided valuable insights into the burden of youth LE injuries on the NZ healthcare system. Inflation-adjusted ACC injury claim costs (adjusted to Q1 2025) (Reserve Bank of New Zealand, 2025) for LE injuries increased by nearly 14% between 2013/14 and 2022/23. When broken down by injury location, average annual costs for knee injuries increased substantially from NZ$162,993 to NZ$265,486, while costs for upper leg and ankle injuries declined, from NZ$49,157 to NZ$33,356 and NZ$65,251 to NZ$52,483, respectively. These trends should be interpreted in the context of rising healthcare costs over this period (Accident Compensation Corporation [ACC], 2025c). Knee injuries were consistently the most costly, with expenses increasing both over time and age. Across all three investigated LE injury locations, the 10-year mean cost per claim was higher in females than males in the 10–19y age group, but higher in males than females in the 20–24y age group. These findings, when considered alongside injury incidence trends, highlight the need for targeted injury prevention strategies to reduce both individual and system-wide costs.

Seasonal Injury Patterns

The analysis of seasonal injury patterns in youth hockey revealed two key periods of elevated injury risk, particularly in players aged 10–19y. The first spike occurred in May and June, coinciding with the start of the hockey season. This was most pronounced in the 15–19y age group, suggesting a need for improved hockey-specific physical preparation during pre-season and trial phases to reduce early-season injury risk. The second spike was observed in August and September, aligning with annual tournament periods. This pattern was most distinct in the 10–14y age group and indicated that tournament-related loading and recovery strategies should be more carefully managed. An example of this in practice is a collaboration between NetballSmart and the AIMS Games, a major intermediate school sports tournament in NZ. Players were allocated time and space to warm-up safely on their court prior to each game, and game length was also reduced, ultimately decreasing player loading by 25% over the weeklong tournament (Belcher et al., 2024). These findings highlight the importance of injury prevention efforts focussed on key seasonal periods to better support youth players' physical readiness and resilience.

Implications for Practice

A key implication of these findings is the need for sport-specific injury prevention strategies that are targeted on the most commonly injured anatomical areas, as it is evident that different team sports show distinct injury location patterns. In youth hockey, priority should be placed on knee injury prevention, as this is the costliest injury location with the highest injury rates and increasing costs over time. Targeting knee injury prevention in older youth hockey players may yield the greatest reduction in both personal and healthcare system burden, given the high injury rates and costs of this age group. Published injury prevention programmes (IPPs) in other popular sports including the FIFA 11+ in football and NetballSmart in netball have demonstrated efficacy in reducing knee injuries (Belcher et al., 2024; Sadigursky et al., 2017), and may provide a useful foundation for future IPP development in hockey.

Alongside sport-specific initiatives, age- and sex-specific IPPs within youth sport should be considered. An example of this could be placing a greater focus on improving neuromuscular control in adolescent female hockey players to reduce LE injury risk and help address the elevated knee and ankle injury rates and costs in females compared to males.

Within youth hockey, and possibly across team sports, it is important to consider the seasonal timing of prevention efforts. Targeted prevention will likely be most effective around the start of the season and annual tournaments. Therefore, pre-season hockey-specific preparation should be considered in youth players, particularly those aged 15–19y. This could include sport-specific conditioning programmes and load management strategies during the trial phase. Around annual tournaments near the end of the hockey season, strategies should be implemented to improve load management, particularly in 10–14y players. During a hockey game, rolling substitutions can be used to better manage player load, particularly over a concentrated period of loading such as a tournament (Furlong & Rolle, 2018). Recovery strategies can also be utilised alongside the existing rules from Hockey NZ that limit game play during these periods (Hockey New Zealand, 2025b, 2025c). Time and space, which have been identified as barriers to IPP adoption, should be allocated throughout the season and during competitions for players to undertake prevention interventions such as neuromuscular warm-ups and other exercise-based IPPs. An example of addressing these barriers is seen in the collaboration between NetballSmart and the AIMS Games to better integrate the NetballSmart IPP at an organisational level. The allocation of time and space to warm-up safely prior to each game alongside the reduction of game length reduced player loading by 25% over the course of the tournament (Belcher et al., 2024). This example highlights the importance of organisational level support, emphasising the value of collaboration in the successful implementation of future IPPs in youth hockey. Engaging hockey players and coaches in the design and development of a future hockey-specific IPP could enhance its compliance and therefore its effectiveness, as demonstrated in other team sports in NZ such as futsal (Tomsovsky et al., 2021; Tomsovsky et al., 2020). This collaborative approach fosters greater engagement and helps ensure the IPP addresses challenges specific to the sporting environment while reflecting the priorities of the players and coaches who will be using it.

Another key implication is the need for greater consensus on the methodology of sport injury surveillance to improve data comparability and therefore provide more clarity around injury trends in youth sport. This may be achieved through the wider adoption of the International Olympic Committee (IOC) consensus statement on methods for recording and reporting sport injury and illness epidemiological data, and the development of sport-specific consensus statements as recommended by the IOC. To date, internationally recognised consensus statements have been developed in football, rugby union, rugby league, and cricket (Bahr et al., 2020). Therefore, sport organisations should consider the establishment of sport-specific consensus statements on sport injury epidemiology in hockey, netball, basketball, and touch rugby. A significant component of improving surveillance is the practical consideration of who is responsible for data collection. One strategy used in a recreational futsal setting in NZ involved referees completing specifically designed and easily understandable injury reporting cards after each game, which were then submitted electronically by court managers on a weekly basis (Tomsovsky et al., 2021). A standardised and simple injury reporting card that could be used by referees, coaches, players, or healthcare professionals to register injuries may help address the practical challenges of injury surveillance in youth sport.

Of the top eight sports by ACC injury claims in NZ that were explored in the systematic review, the only two that do not have a sport-specific version of ACC SportSmart (national IPP) or similar framework in use or in development are hockey and cricket (ACC, 2023, 2025b). The neuromuscular warm up within the SportSmart framework is modelled on the evidence-based FIFA 11+ warm-up, incorporating the three key elements of effective neuromuscular injury prevention: core strength, muscular control and balance, and plyometrics and agility (ACC, 2016). As this thesis has highlighted the importance of sport-specific injury prevention that targets the most commonly injured areas, hockey-specific and cricket-specific versions are worth consideration. In the meantime, the SportSmart neuromuscular warm-up is designed to be used across sports and will likely still have a positive impact if implemented in these sports, as the included exercises help reduce the risk of LE injury, particularly knee ligament injuries (ACC, n.d.). This would be beneficial in hockey given the knee is the most common and costly LE injury location. The SportSmart framework also contains advice and examples for implementation of each of the key injury prevention principles (ACC, n.d.), increasing its usability across sports.

Strengths & Limitations

A key strength of both the systematic review and hockey injury analysis is the use of data over a 10-year period, allowing for the evaluation of trends present in youth sport over the last decade. It is important to note that this period included the Covid-19 pandemic, which significantly impacted sport participation in 2020 and 2021 through the cancellation, modification, or postponement of trainings and competitions to reduce virus transmission (Fitzgerald et al., 2021). The restricted participation levels during the pandemic will have influenced injury data collected during this time, potentially limiting the comparability of this 10-year period to other decades.

An important consideration when looking at the systematic review and hockey injury analysis together is the alignment of the latter with the IOC consensus statement on injury surveillance in youth sport (Bahr et al., 2020), which provides standardised guideline recommendations for recording and reporting injury and illness data in sport. Its aim is to enhance consistency and comparability across studies and support the development of effective injury prevention strategies. The hockey injury review in Chapter 3 was designed with the IOC guidelines and Strengthening Reporting of Observational Studies in

Epidemiology—Sport Injury and Illness Surveillance (STROBE-SIIS) checklist in mind. While the study adhered to several key recommendations, some compromises were necessary due to the nature of available data. Combining the suggested injury locations of "hip/groin" and "thigh" into "hip/upper leg/thigh" was necessary due to the reporting categories of ACC injury data. This allowed for broader inclusion of relevant data but limited anatomical specificity. In the absence of time-based exposure data such as player hours, affiliated member counts were used as the injury incidence rate denominator. This aligns with the IOC guidance that crude injury rates per participant are acceptable when time-based data are unavailable. While the IOC suggests using "injuries per 365 athlete-days" as an alternative when time-based exposure is unavailable, this study opted for "injuries per 1000 affiliated players" to maintain interpretability and facilitate straightforward comparisons across age, sex, and injury location. However, injury rates per 365 athlete-days can be derived to support future comparisons. The 10-year mean LE hockey injury rate represented in this way across youth players is 0.0180 injuries/365 athlete-days (24.65/1000 players). For each injury location, the mean injury rates are 0.0137 injuries/365 athlete-days (21.38/1000 players) for the upper leg, 0.0219 injuries/365 athlete-days (29.05/1000 players) for the knee, and 0.0185 injuries/365 athlete-days (23.50/1000 players) for the ankle. While the hockey injury review did not fully meet all methodological recommendations outlined in the IOC consensus statement, it adhered to its core principles and demonstrated a pragmatic approach to injury surveillance using the best available data. Due to the nature of the dataset, which did not include metrics such as time loss or return to sport, the analysis was unable to assess injury burden at the individual level. Instead, it provided insight into injury burden at the national level, based on injury claim rates and associated costs. These reflections highlight both the strengths of national injury datasets and the ongoing need for improved data collection standards in youth sport.

Future Research Directions

Future research areas should include injury surveillance across the comparatively under researched sports included in the systematic review: netball, hockey, cricket, rugby league, and touch rugby. Due to the current higher volume of research focusing on male populations in youth sport, future research should include female populations to better facilitate between-sex comparisons and highlight differences to inform the continual development of effective injury prevention initiatives. Within hockey, future research directions may include surveillance of injuries involving body locations other than the LE; investigating injury mechanisms, severity, and return to sport; and injury surveillance using player exposure data. As it has been indicated that a hockey-specific injury prevention framework may be beneficial, it will be critical to evaluate the uptake and impact of any future hockey-specific IPP. Across sport, longitudinal studies on IPP effectiveness will help inform future developments and refinements of prevention initiatives to reduce the overall burden of injury in youth sport.

Conclusion

Over the 10-year period from 2013–2023, LQ injuries across youth team sports appeared to remain relatively stable, with no consistent upward or downward trend. When evaluating injury incidence over time by sport, rates were higher in rugby union, fluctuating in football, stable in netball, lower in basketball, and significantly lower in hockey. In youth hockey specifically, LE injury rates declined, with rates 35% lower at the end of the 10-year period. Knee injuries were the most common and costly, particularly in females and older youth players, and seasonal peaks occurred at the start of the season and around annual tournaments. Collectively, the findings of this thesis indicate that IPPs should be tailored by age, sex, and sport based on injury risk profiles, and consideration should be given to the timing of prevention efforts throughout the season, particularly in youth hockey. To better inform injury prevention in sport, greater consensus of injury surveillance methodology is needed. Overall, it is important to implement targeted, evidence-informed injury prevention strategies that reflect the unique demands of youth team sports in NZ.

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Appendix

Supplementary Result Tables

Table A1

JBI Critical Appraisal Tool: Randomised Controlled Trial Design

Question Number	JBI Critical Appraisal Question
Internal Validity	
Bias related to selection and allocation	
1	Was true randomisation used for assignment of participants to treatment groups?
2	Was allocation to treatment groups concealed?
3	Were treatment groups similar at the baseline?
Bias related to administration of intervention/exposure	
4	Were participants blind to treatment assignment?
5	Were those delivering the treatment blind to treatment assignment?
6	Were treatment groups treated identically other than the intervention of interest?
Bias related to assessment, detection and measurement of the outcome	
7	Were outcome assessors blind to treatment assignment?
8	Were outcomes measured in the same way for treatment groups?
9	Were outcomes measured in a reliable way?
Bias related to participant retention	
10	Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analysed?
Statistical Conclusion Validity	
11	Were participants analysed in the groups to which they were randomised?
12	Was appropriate statistical analysis used?
13	Was the trial design appropriate and any deviations from the standard RCT design (individual randomisation, parallel groups) accounted for in the conduct and analysis of the trial?

Table A2

JBI Critical Appraisal Tool: Cohort Design

Question Number	JBI Critical Appraisal Question
1	Were the two groups similar and recruited from the same population?
2	Were the exposures measured similarly to assign people to both exposed and unexposed groups?
3	Was the exposure measured in a valid and reliable way?
4	Were confounding factors identified?
5	Were strategies to deal with confounding factors stated?
6	Were the groups/participants free of the outcome at the start of the study (or at the moment of exposure)?
7	Were the outcomes measured in a valid and reliable way?
8	Was the follow up time reported and sufficient to be long enough for outcomes to occur?
9	Was follow up complete, and if not, were the reasons to loss to follow up described and explored?
10	Were strategies to address incomplete follow up utilized?
11	Was appropriate statistical analysis used?

Table A3

JBI Critical Appraisal Tool: Quasi-Experimental Design

Question Number	JBI Critical Appraisal Question
Internal Validity	
Bias related to temporal precedence	
1	Is it clear in the study what is the “cause” and what is the “effect” (i.e. there is no confusion about which variable comes first)?
Bias related to selection and allocation	
2	Was there a control group?
Bias related to confounding factors	
3	Were participants included in any comparisons similar?
Bias related to administration of intervention/exposure	
4	Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?
Bias related to assessment, detection and measurement of the outcome	
5	Were there multiple measurements of the outcome, both pre and post the intervention/exposure?
6	Were the outcomes of participants included in any comparisons measured in the same way?
7	Were outcomes measured in a reliable way?
Bias related to participant retention	
8	Was follow-up complete and if not, were differences between groups in terms of their follow-up adequately described and analysed?
Statistical Conclusion Validity	
9	Was appropriate statistical analysis used?

Table A4

JBI Critical Appraisal Tool: Analytical Cross-Sectional Design

Question Number	JBI Critical Appraisal Question
1	Were the criteria for inclusion in the sample clearly defined?
2	Were the study subjects and the setting described in detail?
3	Was the exposure measured in a valid and reliable way?
4	Were objective, standard criteria used for measurement of the condition?
5	Were confounding factors identified?
6	Were strategies to deal with confounding factors stated?
7	Were the outcomes measured in a valid and reliable way?
8	Was appropriate statistical analysis used?

Table A5

Systematic Review Key Findings of Included Studies

Study	Injury Location & Type	Estimated Injury Rate
Basketball		
Leppänen et al. (2021)	Noncontact knee total	0.24/1000h
	- Female	0.37/1000h
	- Male	0.17/1000h
	Noncontact ACL	0.03/1000h
	- Female	0.09/1000h
	- Male	-
Barden & Thain (2022)	Lower extremity	3.3/1000AEs
	- Match	10.2/1000AEs
	- Training	2.0/1000AEs
	- Knee	1.5/1000AEs
	- Match	1.2/1000AEs
	- Training	0.6/1000AEs
	- Ankle	1.8/1000AEs
	- Match	5.4/1000AEs
	- Training	1.1/1000AEs
Barden et al. (2021)	Lower extremity (match)	37/1000mh
	- Thigh/groin	3/1000mh
	- Knee	3/1000mh
	- Ankle	24/1000mh
Bittencourt et al., (2019)	Patellar tendinopathy	1.59/1000h
Owoeye et al. (2020)	Lower extremity	12.8/1000h
	- Female	12.1/1000h
	- Male	13.2/1000h
	- Hip/groin	0.10/1000h
	- Female	-
	- Male	0.16/1000h
	- Thigh	0.17/1000h
	- Female	0.24/1000h
	- Male	0.11/1000h
	- Knee	6.49/1000h
	- Female	5.01/1000h
	- Male	7.49/1000h
	- Lower leg	0.36/1000h
	- Female	0.40/1000h
	- Male	0.27/1000h
	- Ankle	5.49/1000h
	- Female	6.20/1000h
	- Male	5.01/1000h
	- Foot	0.13/1000h
	- Female	0.16/1000h
	- Male	0.11/1000h
Emery et al. (2022)	Ankle and knee	11.8/1000h
	- Female	11.3/1000h
	- Male	12.1/1000h
Black et al. (2021)	Lower extremity	12.78/100 players/year
	- Hip/groin/upper leg	0.59/100 players/year
	- Knee	3.93/100 players/year
	- Lower leg	0.79/100 players/year
	- Ankle	7.27/100 players/year
	- Foot	0.20/100 players/year

Study	Injury Location & Type	Estimated Injury Rate	
Stojanović et al. (2024)	Lower quadrant	0.25/1000AEs	0.16/1000h
	- Training	0.08/1000AEs	0.05/1000th
	- Match	2.03/1000AEs	7.58/1000mh
	- Lower back	0.04/1000AEs	0.02/1000h
	- Training	0.04/1000AEs	0.02/1000th
	Lower extremity	0.21/1000AEs	0.13/1000h
	- Training	0.04/1000AEs	0.02/1000th
	- Match	2.03/1000AEs	7.58/1000mh
	- Knee	0.07/1000AEs	0.04/1000h
	- Training	0.04/1000AEs	0.02/1000th
	- Match	0.41/1000AEs	1.52/1000mh
	- Ankle	0.14/1000AEs	0.09/1000h
	- Match	1.62/1000AEs	6.06/1000mh
Cricket			
Keylock et al. (2022)	Lumbar bone stress injury	27.3/100 players/year	
Football			
Zouita et al. (2016)	Ankle sprain	0.54/1000h	
Avedesian et al. (2022)	Lower extremity (musculoskeletal strains & sprains)	2.47/1000AEs	
Jaber et al. (2022)	Lower extremity		
	- Match	5.57/1000mh	
	- Training	0.57/1000th	
	- Hip/groin		
	- Match	0.14/1000mh	
	- Training	0.01/1000th	
	- Thigh		
	- Match	1.65/1000mh	
	- Training	0.17/1000th	
	- Knee		
	- Match	1.33/1000mh	
	- Training	0.13/1000th	
	- Lower leg		
	- Match	0.38/1000mh	
	- Training	0.04/1000th	
	- Ankle		
	- Match	1.39/1000mh	
	- Training	0.14/1000th	
	- Foot/toe		
	- Match	0.70/1000mh	
	- Training	0.07/1000th	
Bacon & Mauger (2017)	Lower quadrant	11.52/1000h	
	- Hip/pelvis/adductor	2.40/1000h	
	- Groin	0.48/1000h	
	- Quadricep/thigh	0.48/1000h	
	- Hamstring	0.72/1000h	
	- Knee	2.40/1000h	
	- Calf	0.48/1000h	
	- Ankle	3.60/1000h	
	- Foot	0.96/1000h	
Olumide & Ajide (2016)	Lower extremity	66.82/1000mh	
	- Hip/groin	20.05/1000mh	
	- Thigh	20.05/1000mh	
	- Knee	20.05/1000mh	
	- Ankle	6.68/1000mh	

Study	Injury Location & Type	Estimated Injury Rate		
Bowen et al. (2017)		2013/14	2014/15	2013-2015
	Lower quadrant	10.7/1000h	12.3/1000h	9.2/1000h
	- Abdomen/lower back	0.4/1000h	0.0/1000h	0.9/1000h
	- - Noncontact	0.4/1000h	0.0/1000h	0.9/1000h
	Lower extremity	10.3/1000h	12.3/1000h	8.3/1000h
	- Hip/groin	1.6/1000h	2.3/1000h	0.7/1000h
	- - Contact	0.3/1000h	0.5/1000h	0.0/1000h
	- - Noncontact	1.3/1000h	1.8/1000h	0.7/1000h
	- Quadriceps	1.0/1000h	1.3/1000h	0.6/1000h
	- - Contact	0.7/1000h	1.1/1000h	0.2/1000h
	- - Noncontact	0.3/1000h	0.2/1000h	0.4/1000h
	- Hamstring	0.9/1000h	0.2/1000h	1.7/1000h
	- - Contact	0.1/1000h	0.0/1000h	0.2/1000h
	- - Noncontact	0.8/1000h	0.2/1000h	1.5/1000h
	- Knee	1.7/1000h	2.0/1000h	1.5/1000h
	- - Contact	0.6/1000h	0.7/1000h	0.6/1000h
	- - Noncontact	1.1/1000h	1.3/1000h	0.9/1000h
	- Lower leg	0.4/1000h	0.4/1000h	0.6/1000h
	- - Contact	0.2/1000h	0.2/1000h	0.4/1000h
	- - Noncontact	0.2/1000h	0.2/1000h	0.2/1000h
	- Ankle/foot	4.7/1000h	6.1/1000h	3.2/1000h
	- - Contact	2.6/1000h	3.3/1000h	1.9/1000h
	- - Noncontact	2.1/1000h	2.8/1000h	1.3/1000h
Hilska et al. (2021)	Lower extremity	5.50/1000h		
	- - Female	6.20/1000h		
	- - Male	5.30/1000h		
	Acute noncontact lower extremity	2.70/1000h		
	- - Female	3.60/1000h		
	- - Male	2.50/1000h		
	- Knee	0.39/1000h		
	- - Female	0.40/1000h		
	- - Male	0.39/1000h		
	- Ankle	0.95/1000h		
	- - Female	1.86/1000h		
	- - Male	0.72/1000h		
	Contact lower extremity	2.70/1000h		
	- Hip/groin	0.10/1000h		
	- Thigh	0.30/1000h		
	- Shin/calf/Achilles tendon	0.30/1000h		
	- Ankle	1.00/1000h		
	- Foot/toe	0.40/1000h		
Bult et al. (2018)	Lower quadrant	7.66/1000h		
	- Lumbar spine/pelvic	0.54/1000h		
	Lower extremity	7.12/1000h		
	- Hip/groin	1.38/1000h		
	- Thigh	1.43/1000h		
	- Knee	1.38/1000h		
	- Lower leg/Achilles tendon	0.74/1000h		
	- Ankle	1.63/1000h		
	- Foot/toe	0.55/1000h		

Study	Injury Location & Type	Estimated Injury Rate	
Nogueira et al. (2017)	Lower quadrant	3.57/1000h	
	- Lower back	0.27/1000h	
	- Pelvis/hip	0.14/1000h	
	Lower extremity	3.17/1000h	
	- Groin	0.41/1000h	
	- Thigh	0.95/1000h	
	- Posterior thigh	0.48/1000h	
	- Anterior thigh	0.47/1000h	
	- Knee	0.53/1000h	
	- Shank/Achilles tendon	0.28/1000h	
	- Ankle	0.83/1000h	
	- Foot/toe	0.17/1000h	
Gupta et al. (2020)		2013/14	2014/15
	ACL (female)	0.19/1000AEs	0.13/1000AEs
	ACL (male)	0.05/1000AEs	0.04/1000AEs
		2015/16	2016/17
	ACL (female)	0.10/1000AEs	0.13/1000AEs
	ACL (male)	0.04/1000AEs	0.02/1000AEs
Sanz et al. (2020)	Hamstring	7.03/100 players/season	
	- U11	3.13/100 players/season	
	- U13	4.17/100 players/season	
	- U15	9.36/100 players/season	
	- U18	16.93/100 players/season	
Cezarino et al. (2020)	Lower quadrant	1.68/1000h	
	- Match	7.13/1000mh	
	- Training	1.29/1000th	
	- Lumbar spine/sacrum/pelvis	0.06/1000h	
	- Match	0.15/1000mh	
	- Training	0.05/1000th	
	Lower extremity	1.63/1000h	
	- Match	6.99/1000mh	
	- Training	1.24/1000th	
	- Hip/groin	0.22/1000h	
	- Match	0.30/1000mh	
	- Training	0.21/1000th	
	- Thigh	0.48/1000h	
	- Match	2.82/1000mh	
	- Training	0.31/1000th	
	- Knee	0.43/1000h	
	- Match	1.49/1000mh	
	- Training	0.35/1000th	
	- Lower leg	0.08/1000h	
	- Training	0.09/1000th	
	- Ankle	0.36/1000h	
	- Match	1.93/1000mh	
	- Training	0.25/1000th	
	- Foot/toe	0.06/1000h	
	- Match	0.45/1000mh	
	- Training	0.03/1000th	
Thiebat et al. (2021)	Lower quadrant	4.33/1000h	
	- U11	1.67/1000h	
	- U16	5.54/1000h	
	- U17	5.75/1000h	
	- Pelvis	0.16/1000h	
	- U16	0.22/1000h	
	- U17	0.10/1000h	

Study	Injury Location & Type	Estimated Injury Rate
Thiebat et al. (2021) *continued*	Lower extremity	4.22/1000h
	- U11	1.67/1000h
	- U16	5.32/1000h
	- U17	5.65/1000h
	- Thigh	1.91/1000h
	- U11	0.78/1000h
	- U16	2.61/1000h
	- U17	2.31/1000h
	- Knee	0.77/1000h
	- U11	0.37/1000h
	- U16	0.99/1000h
	- U17	0.93/1000h
	- Leg	0.46/1000h
	- U11	0.16/1000h
	- U16	0.67/1000h
	- U17	0.55/1000h
	- Ankle/foot	1.09/1000h
	- U11	0.37/1000h
	- U16	1.05/1000h
	- U17	1.86/1000h
Guitart et al. (2022)	Lower extremity muscle	2.68/1000h
	- Time loss	1.34/1000h
	- Non-time loss	1.34/1000h
Asgari et al. (2022)	Lower extremity	7.55/1000h
	- Thigh	2.52/1000h
	- Knee	2.01/1000h
	- Ankle	2.01/1000h
Barden et al. (2021)	Lower extremity (match)	17/1000mh
	Lower extremity (female, match)	16/1000mh
	- Thigh/groin	6/1000mh
	- Knee	1/1000mh
	- Ankle	6/1000mh
	Lower extremity (male, match)	12/1000mh
	- Thigh/groin	5/1000mh
	- Knee	1/1000mh
	- Ankle	4/1000mh
Light et al. (2021)	Lower quadrant	2.29/1000h
	- U11	0.65/1000h
	- U12	1.10/1000h
	- U13	2.72/1000h
	- U14	2.48/1000h
	- U15	2.29/1000h
	- U16	2.16/1000h
	- U18	2.56/1000h
	- U21	4.39/1000h
	- Lower back/pelvis/sacrum	0.16/1000h
	- U12	0.10/1000h
	- U13	0.05/1000h
	- U14	0.19/1000h
	- U15	0.35/1000h
	- U16	0.27/1000h
	- U18	0.06/1000h
	- U21	0.23/1000h

Study	Injury Location & Type	Estimated Injury Rate
Light et al. (2021) *continued*	Lower extremity	2.14/1000h
	- Hip/groin	0.23/1000h
	- U11	0.05/1000h
	- U12	0.14/1000h
	- U13	0.28/1000h
	- U14	0.37/1000h
	- U15	0.35/1000h
	- U16	0.24/1000h
	- U18	0.17/1000h
	- U21	0.29/1000h
	- Thigh	0.60/1000h
	- U11	0.14/1000h
	- U12	0.10/1000h
	- U13	0.33/1000h
	- U14	0.98/1000h
	- U15	0.52/1000h
	- U16	0.51/1000h
	- U18	0.88/1000h
	- U21	1.22/1000h
	- Knee	0.42/1000h
	- U11	0.14/1000h
	- U12	0.33/1000h
	- U13	0.98/1000h
	- U14	0.47/1000h
	- U15	0.45/1000h
	- U16	0.21/1000h
	- U18	0.28/1000h
	- U21	0.70/1000h
	- Lower leg/Achilles tendon	0.21/1000h
	- U13	0.23/1000h
	- U14	0.28/1000h
	- U15	0.14/1000h
	- U16	0.21/1000h
	- U18	0.26/1000h
	- U21	0.49/1000h
	- Ankle	0.41/1000h
	- U11	0.14/1000h
	- U12	0.24/1000h
	- U13	0.38/1000h
	- U14	0.19/1000h
	- U15	0.24/1000h
	- U16	0.48/1000h
	- U18	0.51/1000h
	- U21	0.99/1000h
	- Foot/toe	0.27/1000h
	- U11	0.14/1000h
	- U12	0.19/1000h
	- U13	0.47/1000h
	- U15	0.24/1000h
	- U16	0.24/1000h
	- U18	0.40/1000h
	- U21	0.47/1000h

Study	Injury Location & Type	Estimated Injury Rate
Ruf et al. (2022)	Lower quadrant	30.6/squad season
	- Lumbar spine	1.7/squad season
	- U14	2.7/squad season
	- U15	2.4/squad season
	- U16	0.4/squad season
	- U17	1.8/squad season
	- U19	1.5/squad season
	Lower extremity	28.9/squad season
	- Hip/groin	5.6/squad season
	- U14	6.7/squad season
	- U15	10.9/squad season
	- U16	4.2/squad season
	- U17	5.2/squad season
	- U19	2.4/squad season
	- Thigh	9.2/squad season
	- U14	10.7/squad season
	- U15	15.7/squad season
	- U16	6.9/squad season
	- U17	7.4/squad season
	- U19	6.7/squad season
	- Knee	5.9/squad season
	- U14	8.0/squad season
	- U15	8.9/squad season
	- U16	2.3/squad season
	- U17	4.8/squad season
	- U19	6.1/squad season
	- ACL rupture	0.4/squad season
	- U15	0.4/squad season
	- U16	0.4/squad season
	- U17	0.4/squad season
	- U19	0.6/squad season
	- Ankle	5.9/squad season
	- U14	7.6/squad season
	- U15	7.7/squad season
	- U16	5.4/squad season
	- U17	5.2/squad season
	- U19	4.3/squad season
	- Foot	2.3/squad season
	- U14	3.6/squad season
	- U15	2.4/squad season
	- U16	1.9/squad season
	- U17	2.9/squad season
	- U19	0.9/squad season
Robles-Palazón et al. (2022)	Lower quadrant	3.1/1000h
	- Lower back/sacrum/pelvis	0.2/1000h
	Lower extremity	2.9/1000h
	- Hip/groin	0.5/1000h
	- Thigh	0.9/1000h
	- Knee	0.6/1000h
	- Lower leg/Achilles tendon	0.3/1000h
	- Ankle	0.4/1000h
	- Foot/toe	0.2/1000h
Brow et al. (2021)	Lower quadrant	44.41/1000h
	- Pelvic/lower back	34.38/1000h
	- Knee and below	10.03/1000h

Study	Injury Location & Type	Estimated Injury Rate	
Cairo et al. (2022)	Lower extremity	24.4/100 players/year	
	- Hip/groin/upper leg	3.6/100 players/year	
	- Knee	10.8/100 players/year	
	- Ankle	8.6/100 players/year	
	- Foot/toe	1.4/100 players/year	
Astur et al. (2023)	ACL (U13-U20)	1.96/100 players/season	1.97/100 players/season
	- U13	0.30/100 players/season	0.22/100 players/season
	- U15	1.06/100 players/season	1.45/100 players/season
	- U17	2.82/100 players/season	2.17/100 players/season
	- U20	3.50/100 players/season	4.02/100 players/season
Black et al. (2021)	Lower extremity	17.34/100 players/year	
	- Hip/groin/upper leg	2.79/100 players/year	
	- Knee	5.26/100 players/year	
	- Lower leg	0.62/100 players/year	
	- Ankle	7.43/100 players/year	
	- Foot	1.24/100 players/year	
Sampson et al. (2021)		2020	2021
	Lower quadrant	12.76/1000h	11.62/1000h
	- Time loss	6.50/1000h	7.85/1000h
	- Medical attention	6.26/1000h	3.77/1000h
	- Lower back/sacrum/pelvis	1.50/1000h	1.26/1000h
	- Time loss	1.25/1000h	1.10/1000h
	- Medical attention	0.25/1000h	0.16/1000h
	Lower extremity	11.25/1000h	10.34/1000h
	- Time loss	5.25/1000h	6.75/1000h
	- Medical attention	6.00/1000h	3.59/1000h
	- Hip/groin	2.25/1000h	1.73/1000h
	- Time loss	0.50/1000h	0.63/1000h
	- Medical attention	1.75/1000h	1.10/1000h
	- Thigh	2.00/1000h	3.14/1000h
	- Time loss	1.75/1000h	2.67/1000h
	- Medical attention	0.25/1000h	0.47/1000h
	- Knee	4.26/1000h	2.67/1000h
	- Time loss	1.50/1000h	1.26/1000h
	- Medical attention	2.76/1000h	1.41/1000h
	- Lower leg/Achilles tendon	1.00/1000h	1.10/1000h
	- Time loss	0.50/1000h	0.78/1000h
	- Medical attention	0.50/1000h	0.31/1000h
	- Ankle	1.25/1000h	0.94/1000h
	- Time loss	0.75/1000h	0.78/1000h
	- Medical attention	0.50/1000h	0.16/1000h
	- Foot/toe	0.50/1000h	0.78/1000h
	- Time loss	0.25/1000h	0.63/1000h
	- Medical attention	0.25/1000h	0.16/1000h
Wik et al. (2021)	Lower extremity	10.1/1000h	
	- Hip/groin	1.7/1000h	
	- Thigh	3.0/1000h	
	- Muscle	2.3/1000h	
	- Quadricep	0.7/1000h	
	- Adductor	0.6/1000h	
	- Hamstring	1.0/1000h	
	- Knee	1.6/1000h	
	- Lower leg	1.1/1000h	
	- Ankle	1.7/1000h	
	- Ankle sprain	0.9/1000h	
	- Foot	1.0/1000h	

Study	Injury Location & Type	Estimated Injury Rate
Martínez-Silván et al. (2023)	Lower extremity muscle	9.67/100 players/season
	- Hip flexor	0.85/100 players/season
	- Hip extensor	0.34/100 players/season
	- Adductor	1.87/100 players/season
	- Hamstring	3.73/100 players/season
	- Quadricep	2.21/100 players/season
	- Triceps surae	0.68/100 players/season
Veith et al. (2024)	Lower quadrant	11.0/1000h
	- Time loss	5.9/1000h
	- Non-time loss	5.1/1000h
	- Lower back/sacrum/pelvis	1.1/1000h
	- Time loss	0.6/1000h
	- Non-time loss	0.5/1000h
	Lower extremity	9.9/1000h
	- Time loss	5.3/1000h
	- Non-time loss	4.6/1000h
	- Hip/groin	2.1/1000h
	- Time loss	0.9/1000h
	- Non-time loss	1.2/1000h
	- Thigh	1.8/1000h
	- Time loss	1.3/1000h
	- Non-time loss	0.5/1000h
	- Quadricep	0.7/1000h
	- Time loss	0.5/1000h
	- Non-time loss	0.2/1000h
	- Hamstring	1.1/1000h
	- Time loss	0.8/1000h
	- Non-time loss	0.3/1000h
	- Knee	2.5/1000h
	- Time loss	1.2/1000h
	- Non-time loss	1.3/1000h
	- Lower leg/Achilles tendon	1.5/1000h
	- Time loss	0.6/1000h
	- Non-time loss	0.9/1000h
	- Ankle	1.4/1000h
	- Time loss	0.9/1000h
	- Non-time loss	0.5/1000h
	- Foot/toe	0.6/1000h
	- Time loss	0.4/1000h
	- Non-time loss	0.2/1000h
Obërtinca et al. (2024)	Lower quadrant	3.68/1000h
	- Lower back/sacrum/pelvis	0.70/1000h
	Lower extremity	2.98/1000h
	- Hip/groin	0.39/1000h
	- Thigh	0.92/1000h
	- Knee	0.68/1000h
	- Lower leg/Achilles tendon	0.18/1000h
	- Ankle	0.64/1000h
	- Foot/toe	0.17/1000h
Darragi et al. (2024)	Lower body	2.39/1000h
Hockey		
Barboza et al. (2019)	Lower quartile	3.84/1000h
	- Lower back	0.19/1000h
	Lower extremity	3.65/1000h
Cairo et al. (2022)	Knee	9.2/100 players/year

Study	Injury Location & Type	Estimated Injury Rate	
Netball			
Belcher et al. (2020)	Knee	2014/15	2016/17
	- 10-14yrs	26/1000 members	26/1000 members
	- 15-19yrs	38/1000 members	35/1000 members
	- 20-24yrs	39/1000 members	37/1000 members
	Ankle		
	- 10-14yrs	48/1000 members	46/1000 members
	- 15-19yrs	74/1000 members	73/1000 members
	- 20-24yrs	72/1000 members	63/1000 members
Rugby			
Archbold et al. (2017)	Lower quadrant (match)	13.38/1000mh	
	- Lower back	1.71/1000mh	
	- Sacrum/pelvis	0.07/1000mh	
	Lower extremity (match)	11.60/1000mh	
	- Hip/groin	1.09/1000mh	
	- Thigh	2.52/1000mh	
	- Anterior	1.16/1000mh	
	- Posterior	1.36/1000mh	
	- Knee	3.82/1000mh	
	- Lower leg/Achilles tendon	0.96/1000mh	
	- Ankle	3.07/1000mh	
	- Foot	0.14/1000mh	
Hislop et al. (2017)	Lower extremity	7/1000h	
Leung et al. (2017)	Lower extremity (match)	9.9/1000mh	
	- Hip/groin/thigh	2.0/1000mh	
	- Knee	3.6/1000mh	
	- Leg	1.2/1000mh	
	- Ankle/foot	3.2/1000mh	
Hartwig et al. (2019)	Lower extremity	8.69/1000h	
	- Upper leg	3.34/1000h	
	- Knee	1.11/1000h	
	- Lower leg	1.11/1000h	
	- Ankle	2.45/1000h	
	- Foot	0.67/1000h	
Sewry et al. (2019)	Lower extremity	13.9/1000h	
Barden et al. (2021)	Lower extremity	14/1000mh (Female rugby union)	
		19/1000mh (Male rugby union)	
		11/1000mh (Rugby league)	
	- Thigh/groin	8/1000mh (Male rugby union)	
		3/1000mh (Rugby League)	
	- Knee	9/1000mh (Female rugby union)	
		7/1000mh (Male rugby union)	
	- Ankle	5/1000mh (Female rugby union)	
		3/1000mh (Male rugby union)	
		3/1000mh (Rugby league)	
Cairo et al. (2022)	Lower extremity	20/100 players/year	
	- Hip/groin/upper leg	6.7/100 players/year	
	- Knee	6.7/100 players/year	
	- Ankle	3.3/100 players/year	
	- Foot/toe	3.3/100 players/year	
Murray-Smith et al. (2023)	Lower extremity	7.6/1000h	
	- U13	5.3/1000h	
	- U14	8.3/1000h	
	- U15	7.6/1000h	
	- U16	22.5/1000h	
	- U17	6.5/1000h	

h=hours, mh=match hours, th=training hours, AE=athletic exposures, m=members

Table A6

Annual Hockey Injury Rates and Changes 2013/14–2022/23

	2013 / 14		2014 / 15		2015 / 16		2016 / 17		2017 / 18		2018 / 19		2019 / 20		2020 / 21		2021 / 22		2022 / 23		13 / 14 – 22 / 23
Hip / Upper Leg / Thigh	**Rate**	**% Δ**	**Rate**	**% Δ**	**Rate**	**% Δ**	**Rate**	**% Δ**	**Rate**	**% Δ**	**Rate**	**% Δ**	**Rate**	**% Δ**	**Rate**	**% Δ**	**Rate**	**% Δ**	**Rate**	**% Δ**	**% Δ**
10-14y Female	7.80	-	10.85	39.1% ↑	8.83	-18.6% ↓	7.51	-14.9% ↓	7.65	1.9% ↑	6.93	-9.4% ↓	4.59	-33.8% ↓	5.16	12.4% ↑	3.38	-34.5% ↓	4.21	24.6% ↑	-46.0% ↓
10-14y Male	6.51	-	6.90	6.0% ↑	6.73	-2.5% ↓	5.43	-19.3% ↓	4.45	-18.0% ↓	4.32	-2.9% ↓	3.15	-27.1% ↓	3.91	24.1% ↑	3.92	0.3% ↑	4.43	13.0% ↑	-32.0% ↓
15-19y Female	22.05	-	26.64	20.8% ↑	26.04	-2.3% ↓	22.57	-13.3% ↓	23.52	4.2% ↑	18.06	-23.2% ↓	13.31	-26.3% ↓	19.06	43.2% ↑	12.44	-34.7% ↓	17.67	42.0% ↑	-19.9% ↓
15-19y Male	26.32	-	25.27	-4.0% ↓	27.35	8.2% ↑	23.55	-13.9% ↓	20.09	-14.7% ↓	15.48	-22.9% ↓	14.13	-8.7% ↓	17.77	25.8% ↑	12.64	-28.9% ↓	18.31	44.9% ↑	-30.4% ↓
20-24y Female	44.04	-	53.76	22.1% ↑	45.73	-14.9% ↓	40.74	-10.9% ↓	30.65	-24.8% ↓	29.51	-3.7% ↓	24.13	-18.2% ↓	38.45	59.3% ↑	28.39	-26.2% ↓	32.60	14.8% ↑	-26.0% ↓
20-24y Male	54.75	-	55.32	1.0% ↑	47.39	-14.3% ↓	34.86	-26.4% ↓	38.78	11.2% ↑	40.76	5.1% ↑	26.46	-35.1% ↓	38.86	46.9% ↑	27.33	-29.7% ↓	31.64	15.8% ↑	-42.2% ↓
Knee																					
10-14y Female	20.02	-	22.51	12.4% ↑	21.46	-4.7% ↓	20.64	-3.8% ↓	17.90	-13.3% ↓	16.44	-8.1% ↓	9.71	-40.9% ↓	14.54	49.7% ↑	12.08	-16.9% ↓	13.24	9.6% ↑	-33.9% ↓
10-14y Male	15.28	-	17.45	14.2% ↑	12.06	-30.9% ↓	11.60	-3.8% ↓	10.07	-13.2% ↓	8.33	-17.3% ↓	7.57	-9.2% ↓	9.41	24.3% ↑	8.59	-8.8% ↓	10.12	17.9% ↑	-33.8% ↓
15-19y Female	38.35	-	46.56	21.4% ↑	39.25	-15.7% ↓	36.57	-6.9% ↓	35.12	-4.0% ↓	29.41	-16.3% ↓	17.44	-40.7% ↓	32.04	83.7% ↑	24.64	-23.1% ↓	28.36	15.1% ↑	-26.0% ↓
15-19y Male	34.19	-	35.21	3.0% ↑	28.54	-18.9% ↓	28.29	-0.9% ↓	27.46	-2.9% ↓	24.95	-9.1% ↓	15.37	-38.4% ↓	25.77	67.7% ↑	20.88	-19.0% ↓	23.39	12.0% ↑	-31.6% ↓
20-24y Female	56.90	-	64.03	12.5% ↑	54.22	-15.3% ↓	46.43	-14.4% ↓	34.68	-25.3% ↓	37.28	7.5% ↑	21.41	-42.6% ↓	52.09	143.3% ↑	39.14	-24.9% ↓	41.63	6.4% ↑	-26.8% ↓
20-24y Male	56.36	-	63.67	13.0% ↑	52.22	-18.0% ↓	41.28	-20.9% ↓	45.67	10.6% ↑	40.35	-11.7% ↓	18.85	-53.3% ↓	43.18	129.1% ↑	31.03	-28.1% ↓	32.05	3.3% ↑	-43.1% ↓
Ankle																					
10-14y Female	24.01	-	22.27	-7.3% ↓	21.54	-3.3% ↓	16.68	-22.5% ↓	15.05	-9.8% ↓	14.51	-3.6% ↓	9.36	-35.5% ↓	15.25	63.0% ↑	12.42	-18.6% ↓	14.96	20.5% ↑	-37.7% ↓
10-14y Male	15.59	-	14.00	-10.2% ↓	12.41	-11.4% ↓	10.33	-16.7% ↓	9.61	-7.0% ↓	8.58	-10.7% ↓	6.05	-29.4% ↓	8.81	45.5% ↑	7.37	-16.3% ↓	10.12	37.3% ↑	-35.1% ↓
15-19y Female	37.39	-	42.30	13.1% ↑	34.63	-18.1% ↓	32.66	-5.7% ↓	32.28	-1.2% ↓	24.01	-25.6% ↓	16.72	-30.3% ↓	27.12	62.2% ↑	20.78	-23.4% ↓	19.09	-8.1% ↓	-48.9% ↓
15-19y Male	23.74	-	20.73	-12.7% ↓	23.90	15.3% ↑	18.16	-24.0% ↓	16.97	-6.5% ↓	16.86	-0.6% ↓	10.74	-36.3% ↓	18.15	69.1% ↑	13.46	-25.8% ↓	16.27	20.9% ↑	-31.5% ↓
20-24y Female	50.47	-	44.97	-10.9% ↓	41.96	-6.7% ↓	35.92	-14.4% ↓	33.87	-5.7% ↓	25.24	-25.5% ↓	21.02	-16.7% ↓	37.62	79.0% ↑	26.67	-29.1% ↓	27.89	4.6% ↑	-44.7% ↓
20-24y Male	49.38	-	48.02	-2.8% ↓	38.68	-19.4% ↓	29.36	-24.1% ↓	31.02	5.7% ↑	24.70	-20.4% ↓	17.24	-30.2% ↓	34.11	97.8% ↑	27.79	-18.5% ↓	29.17	5.0% ↑	-40.9% ↓

Note. All injury incidence rates are per 1,000 affiliated players.

Table A7

Annual Hockey Injury Claim Total Costs and Changes 2013/14–2022/23

	2013 / 14		2014 / 15		2015 / 16		2016 / 17		2017 / 18		2018 / 19		2019 / 20		2020 / 21		2021 / 22		2022 / 23		13 / 14 – 22 / 23
Hip / Upper Leg / Thigh	Cost	% Δ	Cost	% Δ	Cost	% Δ	Cost	% Δ	Cost	% Δ	Cost	% Δ	Cost	% Δ	Cost	% Δ	Cost	% Δ	Cost	% Δ	% Δ
10-14y Female	$ 33,172	-	$ 41,318	24.6% ↑	$ 36,778	-11.0% ↓	$ 29,928	-18.6% ↓	$ 32,274	7.8% ↑	$ 33,253	3.0% ↑	$ 27,978	-15.9% ↓	$ 17,726	-36.6% ↓	$ 11,071	-37.5% ↓	$ 10,348	-6.5% ↓	-68.8% ↓
10-14y Male	$ 17,079	-	$ 21,208	24.2% ↑	$ 35,495	67.4% ↑	$ 24,041	-32.3% ↓	$ 15,228	-36.7% ↓	$ 21,357	40.3% ↑	$ 10,248	-52.0% ↓	$ 13,517	31.9% ↑	$ 9,383	-30.6% ↓	$ 11,742	25.1% ↑	-31.2% ↓
15-19y Female	$ 47,888	-	$139,810	192.0% ↑	$149,599	7.0% ↑	$ 83,948	-43.9% ↓	$ 75,814	-9.7% ↓	$124,935	64.8% ↑	$ 44,400	-64.5% ↓	$ 86,352	94.5% ↑	$ 33,598	-61.1% ↓	$ 48,775	45.2% ↑	1.9% ↑
15-19y Male	$ 73,020	-	$ 93,578	28.2% ↑	$ 61,330	-34.5% ↓	$ 76,411	24.6% ↑	$ 55,676	-27.1% ↓	$ 92,932	66.9% ↑	$ 42,337	-54.4% ↓	$ 57,570	36.0% ↑	$ 22,881	-60.3% ↓	$ 41,085	79.6% ↑	-43.7% ↓
20-24y Female	$ 47,259	-	$ 49,997	5.8% ↑	$ 51,780	3.6% ↑	$ 33,200	-35.9% ↓	$ 25,048	-24.6% ↓	$ 33,285	32.9% ↑	$ 28,391	-14.7% ↓	$ 43,464	53.1% ↑	$ 55,016	26.6% ↑	$ 29,157	-47.0% ↓	-38.3% ↓
20-24y Male	$ 76,521	-	$ 45,822	-40.1% ↓	$ 36,595	-20.1% ↓	$ 63,224	72.8% ↑	$ 35,377	-44.0% ↓	$ 81,525	130.4% ↑	$ 23,509	-71.2% ↓	$ 42,217	79.6% ↑	$ 17,511	-58.5% ↓	$ 59,027	237.1% ↑	-22.9% ↓
Knee																					
10-14y Female	$149,746	-	$124,251	-17.0% ↓	$137,595	10.7% ↑	$187,434	36.2% ↑	$ 99,923	-46.7% ↓	$141,009	41.1% ↑	$ 78,672	-44.2% ↓	$128,873	63.8% ↑	$ 74,399	-42.3% ↓	$103,995	39.8% ↑	-30.6% ↓
10-14y Male	$ 66,040	-	$ 74,937	13.5% ↑	$ 36,635	-51.1% ↓	$ 40,215	9.8% ↑	$ 78,862	96.1% ↑	$ 35,787	-54.6% ↓	$ 65,449	82.9% ↑	$ 74,557	13.9% ↑	$ 65,693	-11.9% ↓	$ 85,246	29.8% ↑	29.1% ↑
15-19y Female	$310,225	-	$352,165	13.5% ↑	$279,384	-20.7% ↓	$235,053	-15.9% ↓	$347,862	48.0% ↑	$350,815	0.8% ↑	$219,927	-37.3% ↓	$636,853	189.6% ↑	$317,041	-50.2% ↓	$462,522	45.9% ↑	49.1% ↑
15-19y Male	$148,191	-	$221,492	49.5% ↑	$150,403	-32.1% ↓	$196,036	30.3% ↑	$214,185	9.3% ↑	$247,135	15.4% ↑	$ 90,978	-63.2% ↓	$189,350	108.1% ↑	$181,308	-4.2% ↓	$156,893	-13.5% ↓	5.9% ↑
20-24y Female	$176,292	-	$142,888	-18.9% ↓	$300,703	110.4% ↑	$168,938	-43.8% ↓	$ 96,213	-43.0% ↓	$332,576	245.7% ↑	$ 61,602	-81.5% ↓	$324,338	426.5% ↑	$287,564	-11.3% ↓	$546,946	90.2% ↑	210.3% ↑
20-24y Male	$127,465	-	$298,799	134.4% ↑	$273,282	-8.5% ↓	$303,545	11.1% ↑	$232,273	-23.5% ↓	$216,675	-6.7% ↓	$190,049	-12.3% ↓	$389,876	105.1% ↑	$116,950	-70.0% ↓	$237,313	102.9% ↑	86.2% ↑
Ankle																					
10-14y Female	$ 81,790	-	$ 70,491	-13.8% ↓	$ 85,323	21.0% ↑	$ 90,711	6.3% ↑	$ 83,567	-7.9% ↓	$ 92,741	11.0% ↑	$ 58,498	-36.9% ↓	$ 77,605	32.7% ↑	$ 60,548	-22.0% ↓	$ 48,461	-20.0% ↓	-40.7% ↓
10-14y Male	$ 34,503	-	$ 33,921	-1.7% ↓	$ 37,350	10.1% ↑	$ 35,149	-5.9% ↓	$ 32,867	-6.5% ↓	$ 57,231	74.1% ↑	$ 25,267	-55.9% ↓	$ 38,310	51.6% ↑	$ 18,246	-52.4% ↓	$ 29,869	63.7% ↑	-13.4% ↓
15-19y Female	$114,249	-	$131,512	15.1% ↑	$121,168	-7.9% ↓	$ 99,204	-18.1% ↓	$150,524	51.7% ↑	$106,210	-29.4% ↓	$ 78,851	-25.8% ↓	$109,030	38.3% ↑	$ 74,926	-31.3% ↓	$ 72,276	-3.5% ↓	-36.7% ↓
15-19y Male	$ 53,547	-	$ 62,104	16.0% ↑	$ 52,244	-15.9% ↓	$105,511	102.0% ↑	$ 38,896	-63.1% ↓	$ 60,673	56.0% ↑	$ 44,350	-26.9% ↓	$ 51,254	15.6% ↑	$ 31,245	-39.0% ↓	$ 63,813	104.2% ↑	19.2% ↑
20-24y Female	$ 58,913	-	$ 39,116	-33.6% ↓	$ 47,869	22.4% ↑	$ 36,447	-23.9% ↓	$ 62,394	71.2% ↑	$ 45,213	-27.5% ↓	$ 34,404	-23.9% ↓	$ 92,665	169.3% ↑	$ 45,969	-50.4% ↓	$ 40,224	-12.5% ↓	-31.7% ↓
20-24y Male	$ 48,501	-	$ 51,035	5.2% ↑	$ 64,915	27.2% ↑	$ 37,119	-42.8% ↓	$ 41,768	12.5% ↑	$ 38,421	-8.0% ↓	$ 49,166	28.0% ↑	$ 71,307	45.0% ↑	$ 28,452	-60.1% ↓	$ 60,252	111.8% ↑	24.2% ↑

Note. All costs are in New Zealand dollars (NZ$), adjusted to Q1 2025 using the Reserve Bank of New Zealand Consumer Price Index (CPI).