Epidemiology of squash-related injuries in New Zealand: A review of ten years of Accident Compensation Corporation claims and costs.

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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

Chapters 2 and 3 of this thesis represent stand-alone papers that have been submitted to a peer-reviewed journal for consideration for publication. My contribution and the contribution by the various co-authors to each of these papers are outlined at the beginning of each chapter and in the "candidate contribution to co-authored papers" table. All co-authors have approved the inclusion of the joint work in this Masters' thesis.

Amy Honeyfield

18th August 2024

CANDIDATE CONTRIBUTION TO CO-AUTHORED PAPERS

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ABSTRACT

Squash is a fast-paced racquet sport that has steadily grown in global popularity for decades, now included in the 2028 Olympic Games. This increase in recognition has not been matched in squash-related injury literature. Squash is a physically demanding sport played in close proximity to opponents within a confined space, predisposing players to injury risk. Currently, no epidemiological studies investigate squash-related injury within New Zealand (NZ), and global squash-related injury data is lacking.

The systematic review investigated evidence surrounding most common squash-related injuries and prevention strategies. The epidemiology analysis gathered NZ squash-related injury data to determine common injuries to guide future injury prevention research and strategy development. Systematic searches of Scopus, Google Scholar, and the EBSCOHealth, used keywords related to squash and injury. The database searches were conducted on 26 July 2024 and included literature from 2004 until 2024. Inclusion criteria required studies to report on squash-related injuries and/or squash-related injury prevention strategies and have full text available published in English. Twenty-six articles included in the systematic review were 23 observational and three reviews. Lower limb injuries were reported as most frequent. Injury prevention strategies predominantly targeted severe eye injuries. The included studies were appraised using the Joanna Briggs Institute tools to assess quality and risk of bias for respective article type. Grading of Recommendations Assessment, Development and Evaluation were used to categorise included study evidence certainty based on study design; ranked from Very Low to High.

Data gathered from the Accident Compensation Corporation (ACC), where accidental injuries within NZ are lodged by healthcare providers, were obtained to assess squash-related injury epidemiology. Data were analysed using SPSS statistical software by sex, age, ethnicity, body site, injury type, geographical region, year, and cause of injury. Over the ten-year period 2012 to 2021 investigated in the epidemiological study, 39,949 squash-related injuries were lodged with ACC amounting to N$37,740,867. Lower limb injuries accounted for half of all claims with players aged 40 to 59 years most injured, and females represented one third of claims. Loss of balance/personal control and twisting movements were the most common mechanisms of injury.

The findings of the ACC epidemiology study agreed with literature from outside of NZ. Lower limb injuries continue to be identified as the most prevalent body site reported in squash-related injuries. Very little research has been conducted into the reduction of squash-related lower limb injuries. Based on the systematic review and epidemiology study findings, squash-specific injury prevention strategies are warranted. These should be targeted toward lower limb injuries, especially in men aged over 40 years. Programmes should have a focus on improving balance and proprioception of players, as loss of balance/personal control was the main mechanism of injury in NZ. The production of an injury prevention tool as has been created in NZ for team sports, rugby and netball for example, could be of use to reduce squash-related injury. Uptake of such a strategy may prove difficult as there are no regular trainings or games as with team sports where injury prevention strategies have been implemented previously.

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For chapter 3

Thank you to ACC for collating and providing the data for this analysis.

ETHICS APPROVAL

Ethical approval for the epidemiology study was reviewed and accepted by the Auckland University of Technology Ethical Committee (AUTEC) on 15 November 2022 for three years until 15 November 2025. Approval code: 22/287, also found in Appendix C.

Ethical approval and confidentiality agreement were required with the Accident Compensation Corporation (ACC) who provided the data for the epidemiological study. Terms were drawn up and ethical approval provided on 5 September 2022 as shown in Appendix B.

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LIST OF FIGURES AND TABLES

LIST OF ABBREVIATIONS

ACC = Accident Compensation Corporation

CINAHL = Cumulative Index to Nursing and Allied Health Literature

GRADE = Grades of Recommendation, Assessment, Development and Evaluation

JBI = Joanna Briggs Institute

NZ = New Zealand

NZ$ = New Zealand Dollar currency

PERSiST = PRISMA in Exercise, Rehabilitation, Sport medicine and Sports science

POS = Point-on-serve

PPR = Point-per-rally

PRISMA = Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

PRISMA-S =PRISMA literary search extension

SNZ = Squash New Zealand

WSF = World Squash Federation

ACC = Accident Compensation Corporation

NZ = New Zealand

NZ$ = New Zealand Dollar currency

SNZ = Squash New Zealand

DEFINITIONS

Squash-related Injury

Injury has been defined by the World Health Organization as “a bodily lesion at the organic level, resulting from acute exposure to energy (mechanical, thermal, electrical, chemical or radiant), in amounts that exceed the threshold of physiological tolerance” (World Health Organisation, 2024). In the case of squash-related injuries, injury is sustained through mechanical exposure either through contact with an opponent or object i.e. ball or racquet, or through increased mechanical loading of tissue resulting in tissue failure i.e. twisting or high-velocity movements of the body.

Sport Injury

Sport injuries and the assessment of severity can be determined in numerous ways, including mechanism, clinical diagnoses, player-reported experience and ability to continue, and the data-gathering method. Epidemiological and injury surveillance investigations in sports require researchers to define sport injury and severity within studies to allow meaningful interpretation and practically applicable findings (Finch, 1997).

Sport injuries are defined as any injury occurring during gameplay or training for the purposes of the systematic review presented within this thesis. For studies to be included the injury must be a sport injury resulting from squash, no further restrictions are placed on the definition of squash-related sport injury.

The second manuscript presents a retrospective observational study using injury claim data gathered through the national no-fault claim organisation within New Zealand. As a result, squash-related sport injury is defined for the epidemiological study by the healthcare professional lodging the claim and the description of the injury provided by the player who must identify squash as the cause. Any injury lodged as having occurred due to squash is considered a squash-related sport injury for the study.

CHAPTER 1: INTRODUCTION

1.1 Background

Squash is a racquet sport that originated in the 19th century in England. Students were unable to access racquets courts instead began hitting a punctured rubber ball against outdoor walls, using a long handled, strung racquet. When the ball hit a wall it would squash, giving the game its namesake (Britannica, 2024), with the first indoor squash courts opened in 1864 (Derby, 2016). Following World War I formal rules were established as the game had grown considerably in popularity. The British rules were adopted internationally, with America formulating their own version. The original international rules required the player to have served the ball in order to be awarded a point, known as point-on-serve (POS) play (Britannica, 2024). The POS system resulted in pointless rallies and a lengthy game time resulting in increased demands on players fitness (Murray et al., 2016). In 2009, the rules were standardised globally by the World Squash Federation (WSF) and Professional Squash Association who voted to change scoring to a point-per-rally (PPR) system. Under PPR games were played to 11 or 15 points depending on player age and/or ability, and players were no longer required to hold service of the rally to be awarded a point. This resulted in a reduction of rallies in men's professional matches from 34 to 20 on average when playing PPR to 11 (Murray et al., 2016), with a mean game duration of approximately 15 minutes (Jones et al., 2018). Players of all abilities play for at least seven minutes per game, with a best of five games format (Jones et al., 2018).

Squash popularity continued to grow globally, now with over 115 nations and five regional squash federations as reported by WSF (Britannica, 2024). As a result, squash has been included as a commonwealth games sport since 1998 (New Zealand Olympic Committee, 2024) and recently accepted into the 2028 Olympics after annual consideration since 2012 (Horobeanu et al., 2019; World Squash, 2023). New Zealand (NZ) has had a strong presence in squash, with numerous world champions and medalling at every commonwealth games since the inclusion of squash (New Zealand Olympic Committee, 2024; New Zealand Squash Hall of Fame, 2020). At the most recent Commonwealth Games, NZ won the men's singles, mixed doubles, and women's doubles. Currently, a NZ athlete holds the men's world number two ranking (Professional Squash Association, 2024). With NZ squash continuing to excel, the number of players has also increased with almost 12,000 registered graded players and over 90,000 players in total nationwide (Squash New Zealand, 2023, 2024a).

Squash requires players to perform high-intensity, repetitive and explosive movements in order to play the ball (Horobeanu et al., 2019). Played as either a singles or doubles game, two to four competitors play within the confines of a four-walled 62.5m^2 court in close proximity (Horsley et al., 2020). The fast pace of the game combined with required movements and limited space result in an increased risk of injury, with eye and musculoskeletal soft tissue injuries being most reported in literature (Akl et al., 2021; Black et al., 2017; Horsley et al., 2020; Jones et al., 2018). The lower limb is regularly reported as most injurious body

region across all demographics in available literature (Horsley et al., 2020; Nhan et al., 2018; Sinclair et al., 2017).

Although first introduced in NZ in 1919 and played nationally since 1932 (Derby, 2016), there is a paucity of epidemiological studies investigations squash-related injury within NZ. Available studies focus on specific injuries, such as facial or eye trauma, specific demographics, such as junior and elite players, or geographic locations with one study investigating the epidemiology of injuries in English professional squash players (Atik et al., 2012; Black et al., 2017; Horsley et al., 2020). Many studies are small with poor generalisability due to the narrow population they investigate, with most including less than thirty participants, all of elite or professional squash ability (Akl et al., 2021; Horobeanu et al., 2019; Horsley et al., 2020; Sinclair et al., 2017). Injury prevention data is also scarce for squash-related injuries, with authors instead focusing on serious eye injury prevention through the use of appropriate eye protection (Black et al., 2017; Finch & Eime, 2001).

1.2 Aim of thesis

This thesis aimed to investigate squash-related injuries and injury prevention strategies in NZ and globally by conducting a systematic review and epidemiological analysis of NZ data available through the Accident Compensation Corporation (ACC) database. This approach provided relevant NZ data on squash-related injuries, including mechanisms and characteristics of those injured. Future research will be able to use these findings to guide and develop injury prevention tools and strategies with the hopes to reduce squash-related injuries.

1.3 Research questions

The following research questions were posed and answered in this thesis:

1) What injuries are most common as a result of the sport of squash?
2) Are there any risk factors identified contributing to squash-related injuries?
3) Have any injury prevention strategies been implemented and if so is there any evidence of success?
4) What are squash-related epidemiological and injury patterns and costs in NZ?

1.4 Thesis structure

This thesis follows a manuscript format, whereby two chapters (two and three) were papers prepared for publication. These chapters have been presented in the format required of the journals to which they were submitted, resulting in some repetition of information throughout the thesis. Although able to be presented individually there is a definitive link between these chapters, each is preceded by a prelude linking chapters and providing cohesion. Each of the manuscripts serve to answer the research questions posed above.

This thesis consists of four chapters. Chapter 1 provides background information on squash and current research, acknowledging the gaps in knowledge giving rise to this thesis. Chapter 2 systematically reviews current squash-related injury literature, as no systematic review of squash-related injury literature has been published previously. The EBSCOHealth databases, Scopus database, and Google Scholar were searched, with all article types published since 2004 included provided full text in the English language was available and squash-related injuries or squash-related injury prevention strategies were investigated.

Chapter 3 presents a retrospective epidemiological study into NZ squash-related injuries. Deidentified data retrieved from ACC for squash-related injuries lodged between January 2012 and December 2021, inclusive, was analysed. Data analysis provided insight into squash-related injury mechanisms, locations, and costs, while also providing information on claimant characteristics to inform any common factors in those reporting injuries. In gathering and interpreting this information, question four of this thesis was answered and future directions recommended.

A discussion of findings and limitations of this thesis are presented in Chapter 4, along with recommendations for future research and concluding comments. All reference lists have been removed from the included manuscripts, with a reference section at the conclusion of the thesis presenting all cited material within this work.

PRELUDE TO CHAPTER 2

Current literature reporting squash-related injuries is investigated in this manuscript. As squash grows in popularity, squash-related injuries are likely to increase. Given this, knowledge on squash-related injury mechanisms and prevalence of injuries sustained is needed by researchers and clinicians in order to implement successful injury prevention strategies and tools. Before prevention tools are developed, we must first know what is currently available to squash players and how successful any strategies have been.

This manuscript aimed to gather current information reported on squash-related injuries globally through a systematic search of the literature. Following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and PRISMA extensions guiding search strategy and reporting sport and exercise reviews, a search strategy was developed and carried out.

Information provided by studies published since 2004 in the English language was obtained to answer three of the thesis questions. Firstly, studies reporting squash-related injury body sites and injuries were reviewed to determine the most common injury sustained while playing squash. Secondly, epidemiological data within eligible articles were analysed to uncover any risk factors predisposing squash players to injury. Finally, any papers presenting squash-related injury prevention tools or strategies were evaluated including whether the effectiveness of the injury prevention mechanism was provided.

This review provided relevant information on common squash-related injuries, player and/or game characteristics increasing the risk of squash-related injuries, any strategies currently in place to reduce squash-related injury and the effectiveness of these strategies. This information will guide future squash-related injury studies by identifying areas requiring further knowledge.

CHAPTER 2: LITERATURE REVIEW

SQUASH-RELATED INJURIES: A SYSTEMATIC REVIEW

Overview

Objective Investigate squash-related injuries and prevention strategies in current literature.

Design Systematic review.

Data sources Scopus, CINAHL Complete, Dentistry & Oral Sciences Source, MEDLINE, SPORTDiscus, and Google Scholar were searched on 26 July 2024. Eligible reference lists were reviewed for further studies.

Methods All studies reporting squash-related injuries since 2004 were considered. Studies were restricted to English language and full text available. No restriction was placed on publication country or participant demographics. Twenty-six studies met inclusion criteria. Study certainty and risk of bias was determined using JBI checklists and GRADE.

Findings Based on 17 studies reporting injury site, lower limb injuries were most common. Sixteen studies reporting risk factors identified the physical demands of the game, proximity to opponent, confined court, and high velocity objects (ball and racquet). Injury prevention strategies based on 11 studies were eye protection, footwear, and mouthguards. Limited evidence existed for success with all injury prevention strategies, with eye and mouth protection reported to reduce injury but being poorly adopted by squash participants.

Conclusions Squash-related injuries were most commonly lower limb which was not reflected by injury prevention strategies. Future research should develop and evaluate injury prevention strategies targeted to lower limb injuries to reduce squash-related injuries.

PROSPERO registration number PROSPERO 2024 CRD42024506169.

Highlights

- Lower limb injuries are the most common squash-related injury.
- More risk factors related to gameplay than player characteristics.
- Injury prevention strategies have focused on severe eye injury, not lower limb.
- Development and evaluation of lower limb injury prevention strategies is needed.

2.1 Introduction

Squash is a popular racquet sport involving two players confined to a 62.5m^2 court (Horsley et al., 2020). Continuing to increase in popularity worldwide (Berson et al., 1981; Horobeanu et al., 2019; Mazarelo et al., 2024) and having been considered for Olympic candidacy previously (Horobeanu et al., 2019; Jones et al.,

2018), squash will now be included in the 2028 Olympic Games (World Squash, 2023). To play this high-intensity game, players must perform repetitive, short, sharp, explosive movements in order to alternately hit a small rubber ball which can travel at speeds up to 230km/h (Meyer et al., 2007; Nhan et al., 2018). These movements, such as repetitive lunging, and navigating the small space of the squash court can lead to players sustaining an injury (Finch & Eime, 2001). With the increase in squash participation, the number of squash-related injuries is also likely to rise (Berson et al., 1978; Fong et al., 2007).

Investigations into the performance requirements of squash have documented the need for both aerobic and anaerobic fitness with elite squash players exceeding 90% of their heart rate maximum for approximately a quarter of the time spent playing (Cecchi et al., 2022). This high intensity of play reinforces the need for squash players to be adequately fit and prepared to improve performance and minimise injury risk (Cecchi et al., 2022; Finch & Eime, 2001). The ability to utilise a squash-specific fitness test may be beneficial in determining player skill, fitness, and possibly injury risk, however researchers have reported poor transferability among differing populations such as junior and senior players (James et al., 2019; Wilkinson et al., 2009).

Epidemiological studies have consistently reported over almost four decades from 1981 (Berson et al., 1981) to 2019 (Horobeanu et al., 2019) that soft tissue and lower limb injuries are most common in squash. Given the clear injury epidemiology reported for squash it is surprising that there have been no systematic reviews investigating squash-related injury, risk factors, or injury prevention strategies to the authors knowledge. Therefore, this study aimed to systematically review available literature since 2004 to answer three research questions: What injuries are most common as a result of the sport of squash?; Are there any risk factors identified contributing to squash-related injuries?; and Have any injury prevention strategies been implemented and if so, is there any evidence of success?

2.2 Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021) were followed for this review with consideration to implementing PRISMA in Exercise, Rehabilitation, Sport medicine and Sports science (PERSiST) (Ardern et al., 2022) and the literature search extension PRISMA-S (Rethlefsen et al., 2021). The review protocol was registered with the International prospective register of systematic reviews (Honeyfield et al.) (PROSPERO 2024 CRD42024506169).

2.2.1 Eligibility

2.2.1.1 Types of studies

All study types were considered for this review if squash-related injuries and/or squash-related injury prevention strategies were investigated or documented. Studies published 2004 to present with full text

available and limited to English language were eligible. Those studies discussing squash performance without the inclusion of injury data were excluded from this review.

2.2.1.2 Types of participants

Studies including data on squash players of all ages and levels were included in this review. No studies were excluded due to participant characteristics provided they were injured playing or training for squash.

2.2.1.3 Types of intervention

All included studies were required to document findings of squash-related injury or injury prevention strategies. Some studies that investigated numerous sports for injury epidemiology were included providing findings were documented at an individual sport level. Where combined findings for racquet sports were provided, those combining squash and racquetball were included, as racquetball is played on a standard squash court with a different racquet and ball, therefore experiencing similar playing conditions and demands. Studies combining paddleball and squash were excluded as paddleball conditions were significantly different as paddleball is played outdoors with a single wall in front of competitors (Changstrom et al., 2022)
.

2.2.1.4 Types of outcome measures

The outcomes of interest for this review were body site of squash-related injury, risk factors documented influencing squash-related injuries, and/or changes in injury patterns as a result of squash-related injury prevention strategies.

2.2.2 Information sources

On 26 July 2024 a systematic search was conducted by one researcher using electronic databases MEDLINE, Dentistry & Oral Science Source, SPORTDiscus with Full Text, and Cumulative Index to Nursing and Allied Health Literature (CINAHL) Complete via EBSCOhost. These databases were searched simultaneously using the EBSCOHealth Database platform. An email alert was set up via EBSCOhost to alert for any newly published papers meeting the search criteria to the researcher who completed the initial search. Additional search features in EBSCOhost used were “apply related words”, “apply equivalent subjects”, and the search mode “proximity” where search terms in proximity to one another are included, for example if search terms are separated by five words or less these studies would also appear in the search. A separate search was conducted by the same researcher on the same day on the Scopus database and using Google Scholar to check for further studies or grey literature.

Reference lists of eligible studies were manually screened to identify further studies meeting the search criteria.

2.2.3 Search strategy and study selection

Search terms used were “squash (sport)”, “squash”, “injury”, “injuries”, “accident”, and “trauma” which were combined as shown in Supplementary Table I. No limitations were applied at the initial database searches; however, limitations were applied to the Google Scholar search as detailed in Supplementary Table I.

Following database and web searches, duplicates were manually removed by one researcher. Inclusion and exclusion criteria were then applied to the remaining articles. Publications prior to 2004 were also excluded, and those studies not documenting squash-related injuries or injury prevention in the title or abstract were also removed. Due to language barriers, only those articles with full text available in the English language were eligible for this review. Finally, any results categorised as book chapters or study guides once the full articles were sourced were removed.

The initial search and study selection process including study exclusion details is presented in Figure 2.1. Following the initial database and website search, 56 full text articles were sought for screening and assessed for eligibility. This resulted in 26 studies meeting all inclusion criteria and therefore included in this review.

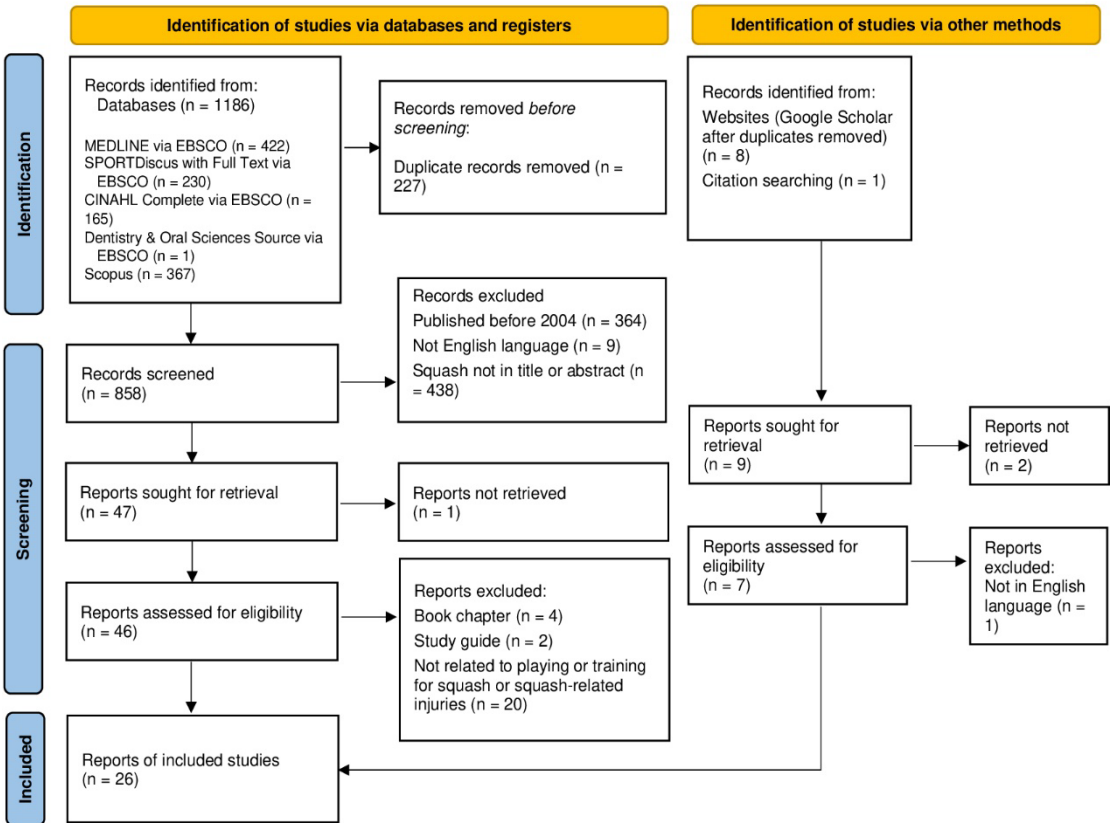

Figure 2.1. PRISMA flow diagram of study selection.

2.2.4 Data extraction

2.2.4.1 Data collection process

Data from studies were extracted by one reviewer into Microsoft Excel spreadsheets and checked by a second author. General study information was recorded, then epidemiological data pertaining to squash-related

injury sites, characteristics of injury risk, and injury prevention strategies and their effectiveness were documented.

2.2.4.2 Data synthesis

Where possible, studies reporting injury incidence and frequency of body sites injured in squash-related events were compared. Due to heterogeneity in injury site reporting and study design, injury sites were recategorised in to “Lower Limb”, “Upper Limb”, “Head/Neck”, “Spine” with a subgroup of “Lower Back” where differentiation was indicated.

A narrative synthesis was deemed most appropriate for this systematic review due to diversity of study design, inconsistent data reporting, and varying study populations indicating considerable clinical heterogeneity rendering meta-analyses inappropriate. Narrative syntheses allow studies with differing designs and characteristics to be analysed together. This approach was guided by Popay et al. (2006). Studies were grouped based on available data to answer the research questions.

2.2.5 Quality assessment and risk of bias

The critical appraisal checklist relevant to study design from the Joanna Briggs Institute (JBI) was used to evaluate included studies. JBI tools were designed for use in systematic reviews to assess methodological quality and determine the extent to which design, conduct, and analytical biases have been addressed (Moola et al., 2020). JBI checklists were selected in favour of alternative quality and risk of bias assessments due to the ability to critique varying observational study designs used to report epidemiological findings. Cochrane guidelines recommend the use of Risk of Bias in Non-randomised Studies (ROBINS) (Sterne et al., 2023), however these do not cater to cross-sectional study designs for example. It has been reported JBI tools provide similar discrimination between studies reporting prevalence for risk of bias as that provided by ROBINS, as well as allowing assessment of studies without a control group (Glasgow et al., 2020). Four different checklists each comprised of eight or eleven questions were used for this review: Cross Sectional study checklist; Case Report study checklist; Systematic Review and Research Syntheses checklist; and the Cohort study checklist (see Supplementary Table II).

Risk of bias was categorised as low, moderate, or high based on the percentage of questions in the relevant JBI checklist answered “yes”. Low risk was defined as more than or equal to 70%, moderate risk was 50-69%, and high risk was 49% or lower. This rating system has been used in previously published literature (Goplen et al., 2019; Melo et al., 2018).

The Grades of Recommendation, Assessment, Development and Evaluation (GRADE) system was used to determine certainty of evidence available from the search strategy. This system considers five factors when determining the evidence certainty: within-study risk of bias (methodological quality), directness of evidence, heterogeneity, precision of effect estimates, and risk of publication bias (Schünemann et al., 2023). The underlying methodology is allocated a baseline rating which can be moved up or down levels as deemed

appropriate by the reviewer. A High rating is assigned to Randomised Controlled Trials, with observational studies deemed a low certainty of evidence due to lack of randomisation resulting in increased potential bias. Case series and case reports are considered very low level of certainty due to no control or comparison group and all participants usually being exposed to the same intervention (Schünemann et al., 2023).

2.3 Findings

2.3.1 Study design and characteristics

Characteristics of the 26 included studies as identified in Figure 2.1 can be found in Table 2.1. The majority of included studies were cross-sectional designs (n=17), with the remaining nine studies made up of case report, systematic review, cohort, and ecological designs (n=3, 2, 2, 1, 1 respectively). Geographical distribution of studies was widespread, with six English studies, five Australian studies, five Middle Eastern (Egypt, Turkey, Iran, and two in Qatar), six Asian (Hong Kong, two Malaysian, three Indian), two European (Germany, Switzerland and France), one South African, and one American study.

Table 2.1 Study characteristics by GRADE rating, with participant characteristics, injury site and incidence.

Author; Year	**Title**	**Study design / Article type / Data collection method; Assessment of certainty (GRADE)**	**Participants (Squash players) (n); Sex (m:f); Age (years); Playing level; Country**	**Incidence; Body site(s)**
Fong et al. (2007)	A systematic review on ankle injury and ankle sprain in sports	Systematic review; High	527 total. 155 retrospective telephone survey (Berson et al., 1981). 372 Retrospective analysis (Chard & Lachmann, 1987); '-. 248:124; <15-26<; 10-50; Public and private club players; Hong Kong	Knee 20.8%. Trunk 15.9%. Ankle 12.6%. Shoulder 7.1%. Leg 2.5%. As indicated by weighted % from two studies reviewed.
Mazarelo et al. (2024)	A systematic review on the effectiveness of eyewear in reducing the incidence and severity of eye injuries in racquet sports	Systematic review; High	-; -; -; -; England	-
Jones et al. (2018)	A review of the performance requirements of squash	Scoping review; Moderate	-; -; -; Elite; England	-
Akl et al. (2021)	Quantifying coordination between agonist and antagonist elbow muscles during backhand crosscourt shots in	Cross-sectional; Low	10; 0:10; 18.4 ± 0.8; International; Egypt	-

	adult female squash players			
Çetinkaya (2018)	Dominant hand usage in racquet sports and detection of the injured regions	Cross-sectional / self-reported surveys; Low	27; 16:11; 18-26; University students not otherwise specified; Turkey	Injuries that occur in the right forearm are more frequently seen among table tennis and squash players. All injury sites reported without indication of incidence: neck, left shoulder, right shoulder, back, upper right arm, left upper arm, waist, right forearm, left forearm, right wrist, left wrist, hips, right upper leg, left upper leg, right knee, left knee, right lower leg and left lower leg.
Eime, Finch, Owen, et al. (2005)	Do squash players accurately report use of appropriate protective eyewear?	Cross-sectional / self -report survey and direct observations by trained observers; Low	1219; -; Adult; -; Australia	-
Eime, Finch, et al. (2004)	Knowledge, beliefs and attitudes of squash venue operators relating to use of protective eyewear	Cross-sectional / Semi-structured interview; Low	13; 9:4; -; 10+; Australia	-
Eime, Finch, Wolfe, et al. (2005)	The effectiveness of a squash eyewear promotion strategy	Ecological / Researcher administered surveys; Low	266/379 pre intervention/post intervention. 170/232 control pre/post.; %m 66/77. 60/80; Median 38/39. 39/37; Social to State level; Australia	-
Eime, McCarty, et al. (2005)	Unprotected eyes in squash: not seeing the risk of injury	Cross-sectional / self-reported anonymous surveys; Low	1163; %m 73.6; Mean 40; Community level with 72.4% having 10+ years' experience; Australia	Eye injuries 19.0 per 100000 players
Horobeanu et al. (2019)	The prevalence of musculoskeletal injuries in junior elite squash players	Prospective cohort / Surveillance record to prospectively collect injury data over 6 years; Low	21; 1:0; Mean 14.5 ± 1.7; Best junior squash players in the country for respective age categories U14-U19; Qatar	7.28 per 1000 hour of training. 3.89 per 1000 hours of squash; Lower extremity 66.9%. Head and trunk 20.4%. Upper limbs 12.7%

Horsley et al. (2020)	The epidemiology of injuries in English professional squash; A retrospective analysis between 2004 and 2015	Cross-sectional / Retrospective analysis of injury records 2004-2015; Low	67; 45:22; Average 25; Elite - funded players; England	Lower limb 76.35%. Head/spine 15.03%. Upper limb 8.45%. Multiple areas 0.17%.
Jendrusch et al. (2022)	Eye injuries in club and school sports – current national figures	Cross-sectional retrospective analysis/Review of sport injury records; Low	2392 eye injuries – not isolated to squash injuries only; -; Average 31.9 ± 16.9; Club level; Germany	Squash was significantly overrepresented among eye injuries reported.
Jhamb and Asundi (2022)	Injuries in Indian squash players: An investigation	Cross-sectional retrospective descriptive/Survey; Low	120; 114:6; Average 41; Club level; India	Lower limb 67.3%. Lower back 12.5%. Upper limb 19.2%. Eye 1%.
Jhamb and Singh (2022)	Injuries in Indian squash players: A retrospective epidemiological survey among club-level players	Cross-sectional retrospective descriptive/Survey; Low	120; 114:6; Average 41; Club level; India	Lower limb 67.3%. Lower back 12.5%. Upper limb 19.2%. Eye 1%.
Meyer et al. (2007)	Prevalence of musculoskeletal injuries among adolescent squash players in the Western Cape	Cross-sectional retrospective descriptive / Self-administered questionnaires; Low	106; 76:30; Average 16.0 ± 1.2; High school squash; South Africa	0.45 per 1000 playing hours; Lower limb 47%. Back 17%. Upper limb 35%.
Nhan et al. (2018)	Epidemiological patterns of alternative racquet-sport injuries in the United States, 1997-2016.	Cross-sectional descriptive epidemiologic study / Data from national injury surveillance database; Low	3487; 2806:680 (1 not recorded); 5-50<; -; America	Lower extremities 34.8%. Head/neck 34.2%. Upper extremities 19.8%. Trunk 9.9%. Not recorded 1.2%.
Okhovatian and Ezatolahi (2009)	Sport injuries in squash	Cross-sectional retrospective / Questionnaire administered in interview with researcher; Low	52; 41:11; Trained m (18) 29.1 ± 13.3. Untrained m (23) 37.6 ± 11.4. Trained f (11) 30.7 ± 12.3; All levels; Iran	Lower back 36.5%. Lower extremities 22% (Hamstring 12%, Knee10%). Upper extremities 21% (Tennis elbow 21%). General strain 19%. Ball kicking 19%. Racquet kicking 19%. Eye 4%
Persic et al. (2006)	Dental squash injuries - a survey among players and coaches in Switzerland, Germany and France.	Cross-sectional / interviews using questionnaire; Low	653 (600 players 53 coaches); -; Average 30.0, range 10-75; 150 players from each division including 50 from each country - junior, amateur, semi-professional, professional; Switzerland, Germany, France	37.7% of all players interviewed suffered an orofacial injury with 4.5% of interviewed players experiencing dental trauma.

Rejeb et al. (2017)	Compelling overuse injury incidence in youth multisport athletes	Prospective cohort / Data from medical records were gathered over five seasons; Low	18; -; Adolescent 12-18; Scholarship; Qatar	8.5 per 1000 playing hours (highest incidence of injury when compared to track and field, table tennis, fencing, gymnastics, swimming, golf, and shooting)
Sankaravel et al. (2017)	Prevalence of musculoskeletal injuries among young squash players in Malaysia	Cross-sectional retrospective / Self-completed questionnaires; Low	60; 29:31; Mean 17.58 ± 3.042; 8.85 ± 3.013 years experience; Malaysia	Neck 16.7%. Shoulder 25%. Elbow 8.3%. Wrist/hand 31.7%. Upper back 16.7%. Lower back 11.7%. Hip/thigh 20%. Knee 20%. Ankle/feet 26.7%. *% = >100 as some players reported more than one injury site
Sinclair et al. (2016)	Influence of minimalist footwear on knee and ankle loads during the squash lunge	Cross-sectional / Ground reaction force and loading through lower limb joints recorded; Low	12; 12:0; 21.59 ± 2.28; Competitive university level; England	-
Sinclair et al. (2017)	Effects of shoes on kinetics and kinematics of the squash forward lunge in male players	Cross-sectional / Ground reaction force and loading through lower limb joints recorded; Low	12; 12:0; 21.59 ± 2.28; Competitive university level; England	-
Tin-Oo and Razali (2012)	Sport-related oral injuries and mouthguard use among athletes in Kelantan, Malaysia	Cross-sectional / structured, interviewer guided questionnaire; Low	21; 11:10; 12 and over; Club level; Malaysia	-
Atik et al. (2012)	Squash(ed): Craniofacial and vertebral injury from collision on squash court	Case report; Very low	1; 1; 55; -; Australia	Craniomaxillofacial fracture 1. Cervical spine 1. Thoracic spine 1.
Mishra et al. (2014)	Reversible blindness following squash ball injury	Case report / Author was participants healthcare professional; Very low	1; -; 27; -; India	-
Patel and Trehan (2007)	Acute isolated acetabular fracture following a game of squash: a case report	Case report; Very low	1; 0:01; 47; 4 years club level experience; England	Hip

A total of 8,626 squash players were included from 21 independent datasets. Two studies reproduced datasets they had previously reported on (Jhamb & Singh, 2022; Sinclair et al., 2017); two were reviews not indicating total number of participants included from primary studies (Jones et al., 2018; Mazarelo et al., 2024); and one did not differentiate between sports for participants instead reporting individual sport injury proportion ratios (Jendrusch et al., 2022) (Table 2.1).

Data were gathered in medical settings such as hospitals in some injury reporting studies (Nhan et al., 2018), with other studies gathering interview and questionnaire data from players within sports facilities such as squash clubs (Jhamb & Asundi, 2022; Sankaravel et al., 2017). The most common form of data collection was survey, questionnaire, or interview (n=12), followed by utilising data available from injury surveillance records (n=5). Nineteen studies were specific to squash, with the remainder also reporting on other sports.

Four studies included only elite squash players or those who were top of their national age group, with a further six indicating club level players were included. All other studies either included all abilities, a specific level of experience based on years played not advising ability or did not specify (Table 2.1).

2.3.2 Critical appraisal and risk of bias

Critical appraisal of included studies using relevant JBI tools indicated mostly low risk of bias, with eight deemed moderate risk (Table 2.1; and see Supplementary Table III). All studies assessed were included, although validity of measures used and consideration of confounding factors on results were not always clear. Closer consideration to selection bias and generalisability when analysing findings of studies only reporting high or low levels of abilities, small sample sizes, and little or no gender diversity.

All included studies were assessed for level of certainty of findings using GRADE scoring (Table 2.1). As most included studies were observational designs, the majority were low certainty (n = 20), with three very low, one moderate, and only two having a high certainty of findings.

2.3.3 Squash-related injury

Based on 16 epidemiology studies (Akl et al., 2021; Çetinkaya, 2018; Eime, McCarty, et al., 2005; Horobeanu et al., 2019; Horsley et al., 2020; Jendrusch et al., 2022; Jhamb & Asundi, 2022; Jhamb & Singh, 2022; Meyer et al., 2007; Nhan et al., 2018; Okhovatian & Ezatolahi, 2009; Patel & Trehan, 2007; Persic et al., 2006; Rejeb et al., 2017; Sankaravel et al., 2017) and one review (Fong et al., 2007), the most common squash-related injuries were to the lower limb, (22-76.4% of all reported injuries) with knee, thigh, and ankle reported as injured most often. Upper limb injuries and trunk/back injuries account for 8.5-65% and 9.9-36.5% of reported injuries respectively (Table 2.1). Five epidemiological studies (Eime, McCarty, et al., 2005; Horobeanu et al., 2019; Jendrusch et al., 2022; Meyer et al., 2007; Rejeb et al., 2017) reported squash injury incidence, however there was inconsistency between study reporting methods. Three small observational studies (Horobeanu et al., 2019; Meyer et al., 2007; Rejeb et al., 2017), all investigating adolescent or junior

squash players, reported incidence per 1000 playing hours ranging from 0.45, 3.89, and 8.5 (Table 2.1). The lower incidence reported by Meyer et al. (2007) included a random population of school aged squash players who had less squash exposure than the smaller studies reporting higher incidence who followed sports academy scholarship players and the top junior players in Qatar (Horobeanu et al., 2019; Rejeb et al., 2017). There is consensus within squash-related injury incidence literature that squash has a moderate to high incidence of injury and is often overrepresented in comparison to other sports injuries.

Despite having world championship squash winners in New Zealand, recent epidemiological studies into squash injuries by the co-authors has highlighted the paucity of research investigating squash injuries in New Zealand (NZ) with only Horsley et al. (2020) referencing a small study (Macfarlane & Shanks, 1998) on back injuries in NZ squash players. Our retrospective analytical review of squash-related injury Accident Compensation Corporation (ACC) claims from 1 January 2012 to 31 December 2021 in NZ (Honeyfield et al., 2024) analysed injury data by sex, age, ethnicity, body site, injury type, geographical region, year, and cause of injury. Over the decade, individuals aged 5 to 89 filed 39,949 injury claims, resulting in ACC incurring NZ$37,740,867 in treatment expenses. Soft tissue injuries, such as sprains and strains, accounted for 93% (37,141) of all claims and 86.4% (NZ$32,596,920.11) of the total costs. Half (50.5%) of the injuries involved lower limbs. Among upper limb injuries, the shoulder was most affected (10.0%), while lower back injuries were also common (15.3%). The age group 40 to 59 years had the highest injury rate (53.7%). Females represented one-third (31.3%) of all injuries. There was a 20% reduction in injuries during 2020 and 2021. The leading causes of injuries were loss of balance/personal control (27.3%), twisting movements (22.4%), and lifting/carrying/strain (16.0%). It was recommended that injury prevention strategies should be focused on preventing lower limb soft tissue injuries by improving balance and twisting control for men aged 40 years and over.

2.3.4 Risk factors documented influencing squash-related injuries

Based on 14 observational studies (Akl et al., 2021; Çetinkaya, 2018; Eime, Finch, et al., 2004; Jendrusch et al., 2022; Meyer et al., 2007; Nhan et al., 2018; Okhovatian & Ezatolahi, 2009; Patel & Trehan, 2007; Persic et al., 2006; Rejeb et al., 2017; Sankaravel et al., 2017; Sinclair et al., 2016; Sinclair et al., 2017; Tin-Oo & Razali, 2012) and two review studies (Jones et al., 2018; Mazarelo et al., 2024), the risk factors identified contributing to squash-related injuries were the high physical demands of the game, close proximity to the opponent, confined court space, and high velocity objects (ball and racquet). Squash demands speed, agility, and explosive repetitive movements, all of which increase loading through the trunk and lower limbs increasing injury risk in these areas (Okhovatian & Ezatolahi, 2009; Patel & Trehan, 2007; Sinclair et al., 2016; Sinclair et al., 2017) (Table 2.2). Increased exposure with more training and playing hours increases risk of both acute and overuse injury in squash players (Rejeb et al., 2017).

Squash itself has been described as a risk factor for injury, with it being documented as a medium risk of resulting in dental injury and being overrepresented in sporting eye injury studies (Jendrusch et al., 2022; Persic et al., 2006; Tin-Oo & Razali, 2012).

Table 2.2 Squash-related injury prevention strategies and injury risk factors.

Author; Year	**Injury prevention strategy and its effectiveness**	**Risk factors documented**
Eime, Finch, Owen, et al. (2005)	Protective eyewear. Self-reported use of appropriate eyewear was significantly higher than on-court observed eyewear behaviour	-
Eime, Finch, et al. (2004)	Protective eyewear. When used, almost completely preventable however fewer than 10% of players wear appropriate eyewear.	Player experience – increased injury risk with inexperience. Poor physical preparation.
Eime, Finch, Wolfe, et al. (2005)	Appropriate protective eyewear promotion – intervention. Use of stickers, posters, and availability of appropriate protective eyewear contributed to players adopting favourable eyewear behaviours.	-
Eime, McCarty, et al. (2005)	Appropriate eyewear protection. 92.2% of adult players are not adequately protecting their eyes	-
Jendrusch et al. (2022)	Sports goggles.	High velocity of the ball. Proximity to player with risk of physical contact with opponent.
Mazarelo et al. (2024)	Eyewear. Compliant with updated standards appeared to reduce eye injury incidence and prevent serious injuries. Once rules on protective eyewear use were introduced, proportion of sports related eye injuries in racquetball and squash dropped from 73% to 23%; wearing eyewear compliant with standards reduced eye injury incidence and severity.	Wearing inappropriate eyewear increases risk of eye injury. Speed of squash ball (up to 220km/h) – more injuries caused by contact with the ball than with opponent. Speed of squash racquet being swung (150-190km/h).
Mishra et al. (2014)	Protective eyewear. Decreased significant eye injury.	-
Persic et al. (2006)	Mouthguard: Tooth rescue kit to prevent long term dental injury encouraged. 1/600 players wore a protective mouthguard - shown to significantly reduce tooth injuries in other sports but not yet investigated in squash.	Low-medium risk of causing dental injuries playing squash - lower playing level and poor knowledge of squash rules such as "Let" rule increase player risk as almost all dental injuries occurred while playing amateurs.
Tin-Oo and Razali (2012)	Mouthguard.	Squash has a medium risk of causing dental trauma due to high velocity, close body contact and the use of racquets.

Sinclair et al. (2016)	Minimalist footwear. Significantly reduces peak knee loading; Increases ankle loading which may increase chance of chronic ankle injury	Repetitive nature and intensity of squash puts players at increased injury risk. Minimalist footwear increased ankle loading which may increase likelihood of chronic ankle injuries.
Sinclair et al. (2017)	Appropriate footwear. Minimalist footwear not advised for squash and continued use of squash-specific footwear recommended.	Increase in impact loading in minimalist footwear may increase risk of impact-related chronic injuries
Akl et al. (2021)	-	Increased co-activation of elbow muscles reduces elbow injury risk.
Çetinkaya (2018)	-	Increased risk of right forearm injuries among squash players compared to other racquet sports. No significant difference to other body areas.
Jones et al. (2018)	-	Physical demands of sport – repeated lunging, accelerations and decelerations, changes of direction.
Meyer et al. (2007)	-	Physical demands of squash. Speed, size, and physical properties of the ball. Court surfaces and the confined playing area resulting in close proximity of players when swinging a racquet. Maturing adolescent musculoskeletal system may increase risk of musculoskeletal injury.
Nhan et al. (2018)	-	Females at a greater risk of injuries to extremities than male players. Males at greater risk of head/neck injuries than female players.
Okhovatian and Ezatolahi (2009)	-	Risk of lower back injury due to combination of rotational and sagittal plane activity of the back motion during squash. Risk of knee injury due to sudden changes in direction as well as twisting movements. Increased playing duration increasing risk of injury.
Patel and Trehan (2007)	-	Weight through hip increases 3 to 5 times body weight during running, jumping, twisting and turning movements needed in squash increasing risk of hip and lower limb injury.
Rejeb et al. (2017)	-	Longer exposure to training of both acute and overuse injury
Sankaravel et al. (2017)	-	Maturing adolescent musculoskeletal system may increase risk of musculoskeletal injury. Biomechanical demands placed on neuro-musculoskeletal system of young people by high intensity sports may be a risk factor. Increased

		risk of wrist and hand injuries in young Malaysian squash players

Several risk factors have been documented that influence squash-related injuries (Table 2.2).

Although unsupported in this review of studies, it has been previously reported players over 40 are at a higher injury risk (Berson et al., 1981), supported by our epidemiological study currently under peer review (Honeyfield et al., 2024).

Poor fitness can increase the likelihood of injuries (Eime, Finch, et al., 2004; Jones et al., 2018; Meyer et al., 2007). Similar to this, the intense physical demands of squash, including rapid movements and high aerobic capacity, also contribute to injury risk(Jones et al., 2018; Meyer et al., 2007; Okhovatian & Ezatolahi, 2009; Patel & Trehan, 2007; Sankaravel et al., 2017; Sinclair et al., 2016; Sinclair et al., 2017). Players lacking in physical fitness likely have a higher injury risk due to having to perform explosive and repetitive movements. This is further compounded by increases in exposure, as the amount of time spent playing can also impact injury risk (Okhovatian & Ezatolahi, 2009; Rejeb et al., 2017).

Poor technique and skill level are significant risk factors (Eime, Finch, et al., 2004; Persic et al., 2006).

Knowledge of squash rules can reduce injury risk, as given the confines of the court the “let” rule exists to mitigate contact injury risk (Persic et al., 2006). Calling “let” without completing a shot indicates the player believes their opponent is positioned either where they will be in contact with the players racquet during swing phase or once struck, the ball will impact the opponent before reaching the front wall (Persic et al., 2006). Players new to the sport may lack knowledge or skill to call “let”, increasing injury risk to their opponent.

Lack of protective gear, especially eye guards, raises the risk of injuries (Eime, Finch, et al., 2004; Eime, Finch, Owen, et al., 2005; Eime, Finch, Wolfe, et al., 2005; Eime, McCarty, et al., 2005; Jendrusch et al., 2022; Mazarelo et al., 2024; Mishra et al., 2014; Persic et al., 2006). However, use of inappropriate protective eyewear not meeting sporting standards increases risk of serious eye injury (Eime, McCarty, et al., 2005; Mazarelo et al., 2024).

Prior or existing injuries can make players more susceptible to new injuries (Horsley et al., 2020). Pre-existing or previous injury can result in altered joint mobility and overall flexibility required to perform movements required in squash, increasing the possibility of sustaining further injury (Horsley et al., 2020).

The speed and size of the ball, the confined playing area, and the court surface can all influence injury risk (Jendrusch et al., 2022; Mazarelo et al., 2024; Meyer et al., 2007; Tin-Oo & Razali, 2012). Risk of injury further increases if these factors are combined with a reduced knowledge or squash ability as noted earlier. Ball and racquet speeds can reach 190 km/h and 220 km/h, respectively (Mazarelo et al., 2024). Impact with either ball or racquet can therefore lead to minor to severe injuries (Mazarelo et al., 2024; Persic et al., 2006; Tin-Oo & Razali, 2012).

These factors highlight the importance of proper training, fitness, and safety measures to reduce the risk of injuries in squash.

2.3.5 Changes in injury patterns as a result of squash-related injury prevention strategies

Injury prevention strategies implemented for squash based on 11 studies were appropriate eye protection (Eime, Finch, et al., 2004; Eime, Finch, Owen, et al., 2005; Eime, Finch, Wolfe, et al., 2005; Eime, McCarty, et al., 2005; Jendrusch et al., 2022; Mazarelo et al., 2024; Mishra et al., 2014), footwear (Sinclair et al., 2016; Sinclair et al., 2017), and mouthguards (Persic et al., 2006; Tin-Oo & Razali, 2012). This demonstrates the injury prevention literature for squash continues to be dominated by severe eye injury prevention using protective eyewear (Bishop et al., 1982; Blonstein, 1975; Eime, Finch, et al., 2004; Eime, Finch, Owen, et al., 2005; Eime, Finch, Wolfe, et al., 2005; Eime, Owen, et al., 2004; Eime et al., 2002; Mazarelo et al., 2024).

There was limited evidence of success with eyewear, mouthguards, and footwear in squash. Where use of protective eyewear was investigated, promotion of appropriate eyewear meeting safety standards improved uptake of this preventative measure (Eime, Finch, Wolfe, et al., 2005). Consensus among authors finds appropriate protective eyewear has the potential to reduce mild and moderate, and prevent serious eye injuries in squash. Mazarelo et al. (2024) reports squash-related eye injury was reduced from 73% to 23% with the introduction of appropriate protective eyewear in their systematic review, however it is reported fewer than 10% of adult squash players wear appropriate eye protection (Eime, Finch, et al., 2004; Eime, McCarty, et al., 2005).

The use of mouthguards in squash was recommended in two cross-sectional studies (Persic et al., 2006; Tin-Oo & Razali, 2012), however uptake was only discussed by Persic et al. (2006) where one of the 600 squash players interviewed wore a protective mouthguard. Authors recognise the possibility for mouthguards to significantly reduce tooth injuries, however this has yet to be explored in squash (Persic et al., 2006).

In 2016 and 2017 Sinclair and colleagues produced papers investigating the impact of footwear on squash-related injuries (Sinclair et al., 2016; Sinclair et al., 2017). The same dataset was used for both studies where 12 male squash players wore different footwear to assess if appropriate footwear could be used to prevent squash-related injuries. Squash-specific footwear is recommended as minimalist shoe types increased loading through players ankles increasing the possibility of developing chronic ankle injuries (Sinclair et al., 2016; Sinclair et al., 2017).

2.3.6 Data limitations and future direction

Although all study designs were eligible for this review, observational studies dominated available literature in the search strategy and study selection. Heterogeneity between sample populations, study design, and data gathering and reporting resulted in an inability to conduct meta-analysis in this review. Limitations of study selection bias may also be evident as only literature published in the English language was included due to language barriers.

Limitations of reviewed studies include small sample sizes, with three case reports and 13 observational designs with a sample of less than 100 squash players. Study samples also limited the generalisability of

findings in some cases, where only one sex was included, or sex distribution was not provided by the authors. In four studies only elite squash players were included, other authors omitted player ability or provided a general statement of competitive, social, or club level players. Reporting club level is vague as some clubs have players varying from beginner to elite ability, leaving included player ability unclear. Age limitations of study samples also impact the generalisability of findings, as four studies exclusively investigated youth or junior squash players.

Squash-related injury data may be under reported in this review as many authors combine squash with other sports in injury incidence studies. Many of these studies were excluded from this review where squash was grouped with sports played in different environments, such as where squash was grouped with badminton or tennis which are not played in a confined space.

Given lower limb injuries were found to be most common in this review, very little has been done to investigate preventative measures of these injuries. Further research into squash-related injuries with more standardised reporting of injury location and incidence are needed to better understand squash-related injuries. Studies into lower limb and musculoskeletal injuries are needed, as this is lacking in current squash-related injury literature. Following the development of further injury prevention strategies, rigorous randomised controlled trials should be completed to determine effectiveness of the injury prevention strategy compared with players usual routine.

2.4. Conclusions

Squash is considered to have a moderate to high risk of injury. Lower limb injuries are most commonly sustained, followed by upper limb, head, and spinal injuries. Injury prevention literature is dominated by squash-related eye injury interventions. Appropriate protective eyewear has been shown to be an effective preventative measure to eye injury, however, protective eyewear has been poorly adopted by squash participants.

There is limited investigation into reducing lower limb injuries in squash, with footwear the only injury preventative strategy reported in this review. It has been suggested by studies reporting squash-related injury incidence that strength, balance, and agility programmes be introduced to reduce musculoskeletal injury in squash. This is supported by this review as soft tissue injuries to the lower limb, upper limb, and trunk were all reported more frequently than bone or organ injury (hip fracture and eye injuries).

Future development of injury prevention strategies targeting lower limb and soft tissue injuries is warranted. Following development, injury prevention data comparing the strategy to players usual routines should be performed with inclusion of all ages and playing abilities to determine effectiveness for injury reduction.

PRELUDE TO CHAPTER 3

Following on from the information gathered in Manuscript 1 presenting current squash-related injury literature globally, NZ specific data is provided in Manuscript 2. This is the first epidemiological study into squash-related injuries in NZ. Data pertaining to squash-related injuries lodged with ACC between January 2012 and December 2021 were analysed to answer the fourth and final question within this thesis.

In NZ, ACC provide a no-fault compensation service for any injuries sustained within NZ, or by NZ residents while out of NZ for six months or less who seek medical treatment on returning (Accident Compensation Corporation, 2024). All injuries lodged are allocated a claim number, and information of the injury, mechanism, and claimant demographics are included in the record (Accident Compensation Corporation, 2023b, 2023c). This database provides a resource for researchers investigating injuries and injury characteristics within NZ.

The ACC also aim to reduce injury within NZ sport through injury prevention schemes at targeted audiences achieved under their SportSmart tools (Accident Compensation Corporation, 2023a). There is currently no SportSmart tool for squash or racquet sports available under this umbrella, instead focusing on team sports such as Rugby Union.

Manuscript 2 utilised deidentified ACC claim data to determine the most common injuries sustained during squash game play or training within NZ. Claimant demographic data were analysed to assist with injury prevention strategies and to target this toward those most at risk of squash-related injury as indicated by ten years of ACC claims. Through answering what the most common and costly squash-related injuries occurring in NZ are, a SportSmart tool for squash could provide a reduction in these injuries and the cost to NZ as defined through ACC compensation data.

CHAPTER 3: ACC EPIDEMIOLOGY

NEW ZEALAND SQUASH INJURIES: ANALYSIS OF TEN YEARS OF ACCIDENT COMPENSATION CORPORATION INJURY CLAIM DATA

Overview

Objectives Provide epidemiological data for squash-related injuries among 5-89-year-olds in New Zealand, to inform the development of an injury prevention programme.

Design Retrospective analytical review of squash-related injury Accident Compensation Corporation (ACC) claims from 1 January 2012 to 31 December 2021.

Methods Data were analysed by sex, age, ethnicity, body site, injury type, geographical region, year, and cause of injury.

Results Over ten years, 5–89-year-olds made 39,949 injury claims, costing ACC NZ$37,740,867 in treatment costs. Soft tissue injuries (i.e., sprains and strains) contributed 93% (37,141) of all claims and 86.4% (NZ$32,596,920.11) of total costs. Half (50.5%) of the injuries were to lower limbs. The most upper limb injuries (20.9%) were to the shoulder (10.0%) while lower back injuries (15.3%) were also prevalent. Players 40 to 59 years old were most frequently injured (53.7%). Females accounted for one-third (31.3%) of all injuries. During 2020 and 2021 there was a 20% reduction in injuries. The most common injury causes were loss of balance/personal control (27.3%), twisting movements (22.4%), and lifting/carrying/strain (16.0%).

Conclusions Injury prevention strategies targeted at preventing lower limb soft tissue injuries by improving balance and twisting control for men aged 40 years and over could provide the greatest reduction in squash-related injury risk.

Highlights

- Soft tissue injuries accounted for 93% of squash injuries in New Zealand.
- Males were injured more frequently than female players, with 68.7% of all injuries.
- Players aged 40 to 59 years were injured most often.
- Loss of balance and twisting movements resulted in the most injuries.

3.1 Introduction

Squash is a high-intensity racquet sport where players are required to perform rapid and explosive movements within a confined space (Horsley et al., 2020; Jones et al., 2018; Locke et al., 1997). The proximity of players combined with the aerobic and anaerobic demands of squash result in an increased risk of injury (Locke et al., 1997), with eye and musculoskeletal soft tissue injuries reported most frequently, and the risk of both acute and chronic overuse injuries (Eime et al., 2003; Finch & Eime, 2001; Horobeanu et al., 2019).

Although requiring repetitive forceful upper and lower limb movements, lower body injuries are more common across all demographics in available literature. A review of all squash studies published since 2011 found one small study (Macfarlane & Shanks, 1998) limited to investigating back injuries in New Zealand (NZ) squash players, highlighting the paucity of research investigating squash injuries in NZ.

Squash has been growing in popularity both globally, and within NZ, and is now confirmed as being included in the 2028 Olympic Games (World Squash, 2023). Annual reports produced by the national governing body for squash in NZ, Squash New Zealand (SNZ) (Squash New Zealand, 2012, 2022), show a 62.7% increase in squash membership nationwide over the review period for this paper of 2012 to 2021. When compared to the most recent annual report for 2022 there is an increase of 84.4% in squash players nationwide since 2012, with SNZ estimating over 90,000 people giving squash a go each year (Squash New Zealand, 2023) and 12,408 graded players currently registered throughout NZ (Squash New Zealand, 2024a). Although able to provide competitive player demographics, SNZ does not gather injury surveillance data.

Within NZ the Accident Compensation Corporation (ACC) provides cover to everyone based on a no-fault scheme if the injury resulted from an accident (Accident Compensation Corporation, 2023d). Treatment costs, income assistance, and home help are examples of assistance provided by ACC cover for accidental injury. Injury prevention tools are provided by ACC in partnership with sporting organisations to produce SportSmart performance and injury prevention programmes (Accident Compensation Corporation, 2023a). These are specific to various sporting codes such as RugbySmart (Smeh & Singla, 2019) and NetballSmart (Kearney, 2019). There is no ACC SportSmart programme for individual sports including squash, however with the substantial increase in New Zealanders participating in squash over the past decade, a tool such as SquashSmart should be considered by ACC and SNZ.

Along with providing compensation and support to injured individuals within NZ, ACC also gather injury and epidemiological data when a claim is lodged (Accident Compensation Corporation, 2023b). This provides opportunity for research into sporting injuries within NZ with decades of data to draw from. The injury mechanism, type, body site, player age, sex, and ethnicity are provided within ACC data (King et al., 2019) which allows analysis into mechanisms, and if epidemiological factors influence these injuries. This paper provides analyses of ACC data on squash injuries between 1st January 2012 and 31st December 2021, presenting epidemiological and injury patterns and costs associated with these injuries. This study aims to inform future direction of injury prevention strategies by establishing commonly occurring injuries resulting from squash.

3.2 Methods

3.2.1 Ethical consent

The ACC dataset is confidential information governed by the Privacy Act 2020 including the Health Information Privacy Code 2020, requiring ethical approval which was obtained from ACC [#050722]. This

research was granted ethical approval by the Auckland University of Technology ethics committee [AUTEC #22/287]. Informed consent from injury claimants was not obtained as the research dataset was deidentified prior to collection from ACC.

3.2.2 ACC injury reporting and data

As SNZ does not gather national squash-related injury data, the ACC database was utilised to obtain nationwide data on squash-related injuries claimed from 1st January 2012 to 31st December 2021. Claims are lodged by a NZ registered healthcare provider when the claimant presents for medical treatment (Accident Compensation Corporation, 2023c). A standardised form is used to record personal and injury details, however, sport-specific data such as level of participation, and any duration of hospitalisation is not documented. The healthcare professional diagnoses the injury, completing the ACC45 injury reporting form which is then entered into the central database (Accident Compensation Corporation, 2023c). Once accepted, ACC provide compensation for the rehabilitation of the personal injury claimed with the aim of returning to baseline activities in a timely manner, such as completing activities of daily living and returning to full duties at work if appropriate.

This study included all squash-related injury claims accepted by ACC throughout the study period. Information on the injured body site, type of injury, mechanism of injury, and participant characteristics such as age and sex were obtained from the dataset.

Demographic data gathered by ACC includes ethnicity, which is categorised into European, Māori, Pacific Peoples, Asian, Residual Categories, and Other. The NZ census information gathered every five years also collects ethnicity data, allowing this study to compare injury data with population data published in the 2018 census (Statistics New Zealand, 2018). As categorisations differ between census and ACC data, ACC Residual Categories and Other were combined, and census data for Middle Eastern/Latin American/African and Other Ethnicity were combined into Other. All other categories were the same between data-gathering agencies. Ethnicity analyses were included as access to education or equipment such as safety gear may be impacted as a result of ethnic status. Geographical location may also impact access, for example, those living rurally or in lower socioeconomic areas may find services or facilities more difficult to come by.

3.2.3 SNZ player data

Squash New Zealand provide a readily accessible database of graded players within NZ. All competitive players must be graded and loaded on to the grading list to be eligible for any competition entry within NZ (Squash New Zealand, 2024b). This allows for some generalisation regarding NZ squash player demographics for competitive players, with sex and age categories reported.

3.2.4 Statistical analysis

The ACC dataset was entered into a Microsoft Excel spreadsheet and cleaned. Due to the nature of ACC data gathering, claims outside of the sport of squash were included in the original dataset such as those resulting from working with the vegetable squash, or having a limb squashed between two surfaces rather than being related to the sport. These claims were removed from analysis. Claimants under 5 and over 90 years old were excluded from analysis as outliers.

Data were analysed using SPSS (IBM Corp. Released 2022. IBM SPSS Statistics for Windows, Version 29.0. Armonk, NY: IBM Corp). All costs are reported in NZ dollars (NZ$).

Injury incidence was not calculated due to squash participation rates in NZ being unavailable. Injuries were compared to NZ population statistics based on the 2018 census which was the most recent data available at the time of this study (Statistics New Zealand, 2018).

Injury rate per 100,000 players were calculated using the average annual injuries over the study period of ten years, and the data available through SNZ for registered players and estimation of total annual players.

$$Injury\ rate\ per\ 100{,}000\ players = \left(\frac{avg.\ injuries\ per\ year}{number\ of\ players\ per\ year}\right) \times 100{,}000$$

3.3 Results

A total of 39,949 claims lodged with ACC between 1st January 2012 and 31st December 2021 were documented as squash-related injuries, amounting to NZ$37,740,867. Claims numbers by year were consistently between 4,000 to 4,300 for 2012 to 2019 (~10% per year of the total claims in the dataset), except for the covid play interrupted years of 2020 and 2021 where there were around 8% per year (~3,200) of the total claims in the data (Supplementary Table IV). Injury prevalence ranged from 32,196.16 to 4,438.78 injuries per 100,000 participants as derived from SNZ reported graded players (12,408 players) and SNZ estimated nationwide players per year (90,000 players), and ACC injury claims lodged throughout the study duration (39,949 claims).

3.3.1 Age and sex

Age was grouped by decade for analysis. Over half of all injured were between 40 and 59 years old, with those 50 to 59 years accounting for 29.5% of all injuries. This age range had the highest cost over the study period of NZ$10,894,909.37. Those aged 40 to 49 followed closely behind with 24.2% of registered claims, costing NZ$10,582,303.63. Players aged 19 years and under were the least injured with 2.8% total injuries costing NZ$331,894.00 (Table 3.1).

Male squash players consistently reported injuries more frequently than females across all age categories, as demonstrated in Figure 3.1. Overall men lodged 27,435 injuries (68.7% total claims) and women reported 12,514 claims (31.3% total claims) during the study period (Table 3.1).

Table 3.1 Claims numbers and costs by age range and sex.

Age range	Number of claims	% total claims	Total cost NZ$	% total cost	Male claims	Cost male claims NZ$	% male claims of total cost	Female claims	Cost female claims NZ$	% female claims of total cost
<10	16	0.0	3,386	0.0	12	2,546	0.0	4	839	0.0
10-19	1,136	2.9	328,507	0.9	710	194,020	0.5	426	134,486	0.4
20-29	4,053	10.1	2,605,084	6.9	2,586	1,549,046	4.1	1,467	1,056,037	2.8
30-39	6,581	16.5	6,927,504	18.4	4,498	4,618,858	12.2	2,083	2,308,464	6.1
40-49	9,669	24.2	10,582,303	28.0	6,335	7,554,162	20.0	3,334	3,028,140	8.0
50-59	11,790	29.5	10,894,909	28.9	8,057	7,680,405	20.4	3,733	3,214,504	8.5
60-69	5,513	13.8	5,490,754	14.5	4,271	4,493,688	11.9	1,242	997,066	2.6
70-79	1,068	2.7	868,605	2.3	858	767,562	2.0	210	101,043	0.3
≥80	123	0.3	39,811	0.1	108	35,336	0.1	15	4,475	0.0
Total	39,949	100.0	37,740,867	100.0	27,435 (68.7%)	26,895,628	71.3	12,514 (31.3%)	10,845,239	28.7

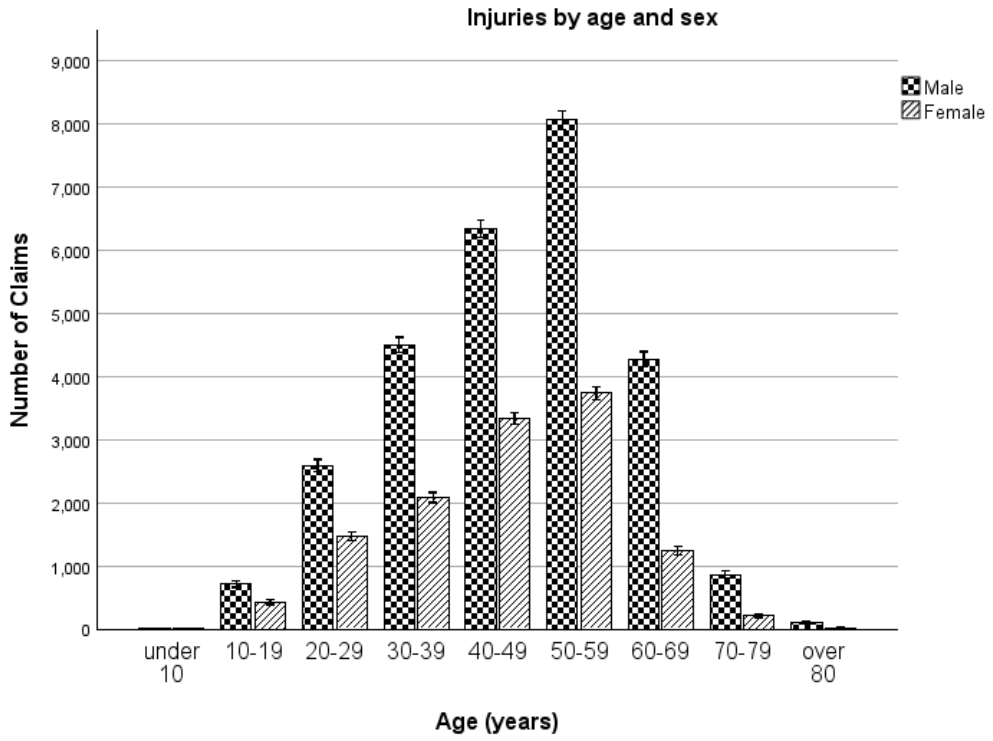

Figure 3.1. Total number of injury claims for age range and sex (95% confidence interval).

Men aged 40 to 59 years old resulted in the highest total claim costs at NZ$15,234,568.08 with 40- to 49-year-old men and 50- to 59-year-old men accounting for 20.0% and 20.4% total cost of claims respectively.

The SNZ grading list reported a total of 12,409 New Zealanders registered as graded. Men accounted for two thirds of these players (67.3%, 8,356 players). Age categories were grouped into Junior (under 19 years old), Senior (19 to 35 years old), and Master (over 35 years old). Over half of all graded players were over 35 years old (7,125 players) with men making up 67.8% of these (Supplementary Table V).

3.3.2 Ethnicity

Most claimants identified as European (n=31,005, 77.6%) which was in keeping with population statistics within the 2018 census with Europeans accounting for the largest proportion of the population (70.2%) (Table 3.2). Māori was the second largest ethnicity reporting squash injuries during the study period, followed by Other, Asian, and finally Pacific Peoples. This differed slightly from population statistics, as the 2018 census documented Other Ethnicities as representing only 2.7% of the population whereas 7.0% of claimants identified within this category. The percentage of total cost mirrored the percentage of claims within each ethnic group with Europeans costing the most (NZ$29,484,439; 78.1%) and Pacific Peoples resulting in the lowest cost with just 2.3% of the total cost of claims.

Table 3.2 Claims and population distribution by ethnicity.

Ethnicity	**Population recorded in 2018 census**	**% population recorded in 2018 census**	**Number of claims**	**% total claims**	**Cost NZ$**	**% total cost**
European	3,297,864	70.2	31,005	77.6	29,484,439	78.1
Asian	707,598	15.1	1,981	5.0	1,314,809	3.5
Māori	775,836	16.5	3,518	8.8	3,578,554	9.5
Pacific Peoples	381,642	8.1	655	1.6	824,594	2.2
Other [a]	128,385	2.7	2,790	7.0		
Other Ethnicity					1,677,954	4.4
Residual Categories					860,516	2.3
Total	4,699,755	112.6 [b]	39,949	100.0	37,740,867	100

[a] Other includes Other Ethnicity and Residual Categories as categorised by ACC, and Middle Eastern/Latin American/African and Other Ethnicity as categorised within the 2018 census

[b] Percentage equals more than 100 as respondents may identify as more than one ethnicity

3.3.3 Geographical region

The top five most populous NZ regions according to the 2018 census also reported the highest percentages of claims over the study period (Statistics New Zealand, 2018). Over a quarter of all those injured resided in the Auckland region (26.1%) which was the most populated NZ region (33.4% of population). Although the Waikato region was the fourth most populated region at 9.7% of population, it recorded the second highest number of injuries with 5,435 claims (13.6% of total claims). Other populous regions of New Zealand also had high percentages of lodged claims (Canterbury 11.6%, Wellington 9.7%, Bay of Plenty 9.4%) (Supplementary Table VI).

3.3.4 Body site and injury type

Most squash injuries were classified as soft tissue with 37,141 claims making 93.0% of all claims and costing NZ$32,596,920.11 (86.4% of total claim costs) over the study period (Table 3.3). Of these soft tissue injuries, 68.4% occurred in men (25,399 claims).

Table 3.3 Injury diagnosis by sex and cost.

Diagnostic Description	Number of claims	% total claims	Male	Female	Cost NZ$	% total cost
Concussion	72	0.2	36	36	205,501	0.5
Contusion	1	0.0	1	0	3,863	0.0
Dental trauma	486	1.2	336	150	371,990	1.0
Foreign body in eye/orifice	11	0.0	5	6	1,872	0.0
Fracture/ dislocation	724	1.8	583	131	2,257,643	6.0
Gradual process	74	0.2	59	15	251,085	0.7
Hernia	4	0.0	4	0	30,390	0.1
Laceration, puncture, sting	714	1.8	583	131	347,194	0.9
Other	591	1.5	417	174	1,594,881	4.2
Pain syndromes	121	0.3	87	34	41,873	0.1
Soft tissue injury	37,141	93.0	25,399	11,741	32,596,920	86.4
Traumatic hearing loss	10	0.0	6	4	37,650	0.1
Total	39,949	100.0	27,435	12,514	37,740,867	100.0

The most commonly injured body site was the lower back/spine (6,113 claims, 15.3%) followed closely by the knee (6,032 claims, 15.1%) (Table 3.4), which is consistent when considering only soft tissue injuries as shown in Table 3.5. However, knee injuries resulted in the highest cost with 30.2% (NZ$9,832,312.89) of all soft tissue injury claim costs and 27.5% (NZ$10,382,433.94) of total claim costs.

Table 3.4 Injury body site by sex and cost.

Injury Body Site	Number of claims	Male	Female	% total claims	Cost NZ$
Abdomen/Pelvis	547	352	195	1.4	181,622
Ankle	5,161	3,480	1,681	12.9	8,087,284
Chest	377	283	94	0.9	111,234
Ear	36	26	10	0.1	53,103
Elbow	657	459	198	1.6	296,989
Eye	383	276	107	1.0	239,654
Face	963	697	266	2.4	528,007
Finger/Thumb	406	274	132	1.0	190,270
Foot	1,347	932	415	3.4	910,723
Hand/Wrist	1,193	795	398	3.0	1,075,139
Head (except face)	179	105	74	0.4	304,757
Hip, Upper Leg, Thigh	3,596	2,582	1,014	9.0	2,008,026
Knee	6,032	4,138	1,894	15.1	10,382,433
Lower Back/Spine	6,113	4,356	1,757	15.3	3,634,387
Lower Leg	3,811	2,550	1,261	9.5	1,813,860
Lung	1	1	0	0.0	6,869
Multiple Locations	27	19	8	0.1	11,478
Neck, Back of Head Vertebrae	1,870	1,129	741	4.7	982,438
Nose	90	54	36	0.2	48,755
Shoulder (including clavicle/ blade)	4,004	2,794	1,210	10.0	5,410,357
Toes	212	165	47	0.5	90,557
Upper and Lower Arm	2,073	1,379	694	5.2	1,105,577
Upper Back/Spine	849	573	276	2.1	242,576
Unobtainable	22	16	6	0.1	24,759
Total	39,949	27,435	12,514	100.0	37,740,867

Table 3.5 Soft tissue injury claims by body site and cost.

Injury body site for soft tissue injury claims	Number of soft tissue injury claims	% of number of soft tissue injury claims	Cost of soft tissue injury claims NZ$	% of cost of soft tissue injury claims
Abdomen/Pelvis	512	1.4	169,716	0.5
Ankle	5,063	13.6	7,658,968	23.5
Chest	320	0.9	75,795	0.2
Ear	15	0.0	2,240	0.0
Elbow	602	1.6	243,085	0.7
Eye	244	0.6	132,629	0.4
Face	146	0.4	38,370	0.1
Finger/Thumb	316	0.9	126,845	0.4
Foot	1,237	3.3	505,740	1.6
Hand/Wrist	1,098	3.0	844,698	2.6
Head (except face)	36	0.1	49,831	0.2
Hip, Upper Leg, Thigh	3,555	9.6	1,565,226	4.8
Knee	5,854	15.8	9,832,312	30.2
Lower Back/Spine	5,995	16.1	3,588,064	11.0
Lower Leg	3,438	9.3	1,381,426	4.2
Multiple Locations	22	0.1	8,808	0.0
Neck, Back of Head Vertebrae	1,860	5.0	971,597	3.0
Nose	36	0.1	11,900	0.0
Shoulder (including clavicle/ blade)	3,862	10.4	4,265,605	13.0
Toes	124	0.3	45,559	0.1
Upper and Lower Arm	1,945	5.2	847,976	2.6
Upper Back/Spine	845	2.3	220,056	0.7
Unobtainable	16	0.0	7,463	0.2
Total	37,141	100.0	32,596,920	100.0

When considering injury sites grouped into lower body, upper body, and spine (Figure 3.2), injuries to the lower body were most common (20,159 claims, 50.5% total claims), followed by the spine (8,832 claims, 22.1% total claims), and then upper body injuries (8,333 claims, 20.9% total claims). Men reported more than twice as many injuries as women in all three injury sites (male claims: 13,847 lower body, 68.7%; 6,058 spine, 68.5%; 5,701 upper body, 68.4%).

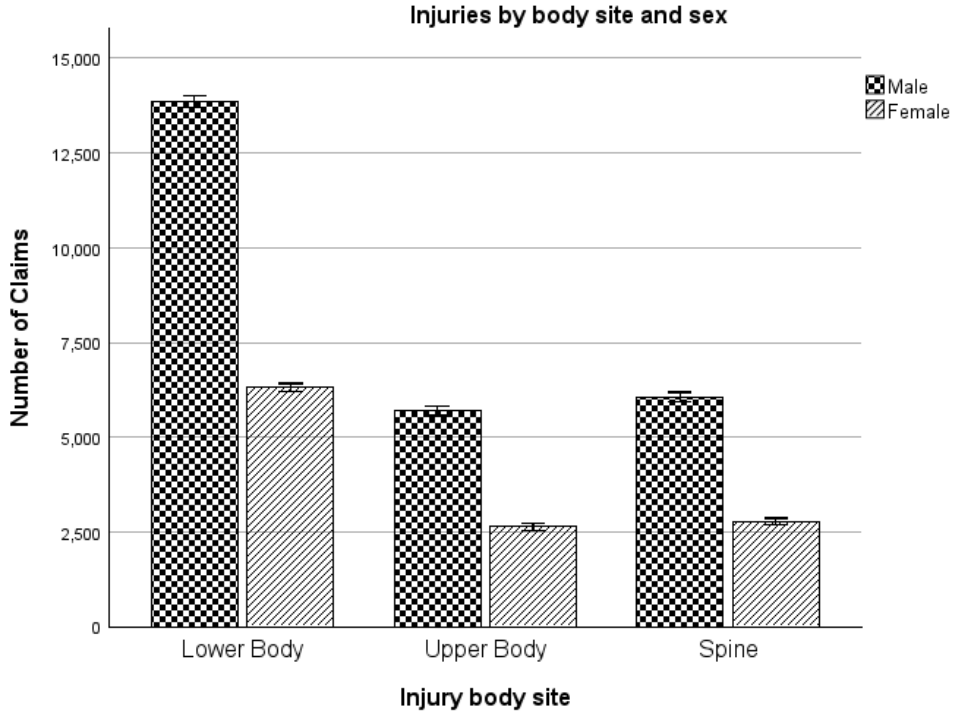

Figure 3.2. Injury claims by body site grouped into lower body, upper body, and spine, by sex (95% confidence intervals).

3.3.5 Mechanism of injury

The top mechanism of squash-related injury (Table 3.6) was loss of balance/personal control, resulting in 10,916 claims (27.3% total claims) and costing NZ$10,394,252.71 (27.5% total costs). This was closely followed by twisting movements which caused 8,935 claims (22.4% total claims), costing NZ$9,857,229.29 (26.1% total costs).

Table 3.6 Top ten causes of injury and cost.

Cause of injury	Number of claims	% total number of claims	Cost NZ$	% total costs
Loss of balance/personal control	10,916	27.3	10,394,252	27.5
Twisting movement	8,935	22.4	9,857,229	26.1
Lifting/carrying/straining	6,374	16.0	5,442,145	14.4
Pushed/pulled	3,924	9.8	3,012,873	8.0
Collision/knocked over by object	3,138	7.9	2,781,880	7.4
Other/unclear cause	1,748	4.4	1,434,638	3.8
Slipping/skidding on foot	1,491	3.7	1,200,250	3.2
Tripping or stumbling	960	2.4	1,518,070	4.0
Struck by person	479	1.2	357,425	0.9
Swerving/evasive action	473	1.2	510,105	1.4

3.4 Discussion

Squash is becoming increasingly popular with more than 90,000 New Zealanders giving the sport a go each year, of which there are 12,408 graded competitive players currently registered in NZ. Squash is now included in the 2028 Olympic Games (Squash New Zealand, 2023, 2024a; World Squash, 2023). With this increase in participation, an increase in number of injuries related to the sport can be expected. This study aimed to analyse the epidemiological and injury data gathered by ACC to guide future injury prevention strategies within the growing game of squash.

There were very few published investigations into squash-related injuries in NZ prior to this study. Injury prevention research in NZ for squash consisted of one prospective study in 1980 that investigated head and facial injuries (Clemett & Fairhurst, 1980), and one retrospective study published in 1998 that explored back injuries in competitive squash players (Macfarlane & Shanks, 1998).

The current NZ study findings of 93% soft tissue injuries aligned with global research (Berson et al., 1978; Berson et al., 1981; Horsley et al., 2020; Nhan et al., 2018) which indicate soft tissue lower limb injuries as most common, accounting for 91% of squash-related injuries. The fast and repetitive acceleration/deceleration movements combined with changing direction during squash games demand rapid responses in muscle activity. This contributes to the high rate of soft tissue injuries sustained by squash players. The NZ soft tissue injuries were categorised into more than 20 body sites through ACC reporting systems. The body site with the largest number of claims during the study period was the lower back/spine (15.3%), however, when injury sites are grouped into upper body, lower body, and spinal injuries, the lower body was injured most often with 50.5% of claims. Chard and Lachmann (Chard & Lachmann, 1987) found over half of all injuries were to the lower limb in their eight-year retrospective study on racquet sports published in 1987. Epidemiological studies in America (data from 1997 to 2016 sourced from the National Electronic Injury Surveillance System database which records injuries presenting to emergency departments) (Nhan et al., 2018), and England (data from 2004 to 2015 sourced from injury records for athletes funded by England Squash and published by the English Institute of Sport and England Squash) (Horsley et al., 2020) both reported soft tissue injuries to the lower limb were most frequent among squash players. A further American study published in 1981 consisting of telephone surveys to randomly selected squash players also reported soft tissue injuries as being most predominant (Berson et al., 1981). This highlights the importance of focusing on injury prevention strategies for soft tissue injuries to the lower limb in particular.

Another American study (Changstrom et al., 2022) investigating racquet sport injuries presenting to the emergency department between 2007 and 2016 observed 60.3% of those injured were men. In the study by Chard and Lachmann (Chard & Lachmann, 1987), 66.7% of squash injuries over the English study were male. Another study (Nhan et al., 2018) found 80% of all injured squash players presenting to emergency departments in America were male. These studies aligned with our findings where 68.7% of squash-related injuries reported to ACC during the study period were sustained by men, however, this finding was not unusual with men accounting for two-thirds of competitive graded squash players in NZ at present.

The most frequently injured age group was between 50- to 59-year-olds, closely followed by 40- to 49-year-olds, collectively accounting for more than half of all injuries. As over half of the current NZ squash grading list was over 35 years old this was not unexpected, however, it was in keeping with existing research in 1981 (Berson et al., 1981) where individuals aged 40 years and older were at a higher risk of squash-related injury. Changstrom, McBride, and Khodaee (Changstrom et al., 2022) reported racquet sport-related injuries occurring in those over 40 years old in 43.8% of men and 41.1% of women with the highest number of squash-related injuries in those over 39 years of age. To reduce squash-related injuries, existing and current data supports investigation into injury prevention strategies targeted toward men over 40 years of age as being most beneficial, especially given this demographic is also the costliest to ACC.

Mechanism of injury is a broad category within ACC data collection, with 35 mechanisms documented for the current study. The most common causes for squash-related injury were loss of balance/personal control (27.3% of claims), twisting movements (22.4% of claims), and lifting/carrying/strain (16.0% of claims). Existing published squash injury data available for review has omitted mechanism of injury, possibly due to data collection processes largely being retrospective and this information being unavailable. Authors were unable to find any data relating to mechanism of injury for squash-related injury, with published research largely reporting injury type and body site along with patient demographic data. Based on the current study, injury prevention strategies targeted at improved balance and improving surefootedness among squash players may reduce injuries as a result of loss of balance and falls.

Available data provides average injuries per year over the study period (3,995 claims), and a range of squash players within NZ can be estimated by SNZ data of 90,000 players per year and 12,408 competitive players registered on the NZ grading list. This allows for the range of injury rate to be estimated, resulting in 4,438.78 to 32,196.16 injuries per 100,000 squash players per year. Earlier studies reporting squash-related injury prevalence provided incidence per 1,000 hours of exposure (Horobeanu et al., 2019) which was not comparable to data derived from the current study. One study published in 2003 (Eime et al., 2003) also reported injury rates per 100,000 players. Data were obtained from hospitals across Victoria, Australia from 1997 to 2001. Injury rates were derived through hospital admission and emergency department presentation data combined with data provided by the Victorian Squash Federation on the number of competitive and social players within Victoria. Squash injuries presenting or being admitted to Victorian hospitals resulted in an injury rate of 80.9 injured players per 100,000 squash players. This was considerably lower than the estimates of the current study. The substantial difference between reported injury rates by Eime et al. (2003) and current findings is likely due to data gathering methods. While Eime et al. (2003) were limited to injuries presenting to hospital emergency departments and hospital admissions, indicating a high severity, the present study included all injuries lodged through primary care providers as well as those presenting to hospital or urgent care facilities. This allowed for the capture of mild to severe injuries, resulting in a higher number of injuries recorded over the study period and a higher injury rate overall.

A 20% reduction in injury claims per year reported to ACC was noted in the years 2020 and 2021 when compared to all other years. This was likely due to the Coronavirus (COVID-19) outbreak globally and subsequent durations of isolation and lockdown which limited the ability for New Zealanders to participate in sports in confined spaces, even once the lockdown periods were eased (Unite against COVID-19, 2022). Squash NZ reported a medium impact of COVID-19 on operations and business in their 2022 annual report (Squash New Zealand, 2022).

Unlike current sports with ACC SportSmart programmes (Accident Compensation Corporation, 2023a), squash is primarily an individual sport without regular training or coaching outside of the highly competitive and elite players. This poses a challenge with implementing an injury prevention programme, which would often be performed at team trainings (Kearney, 2019). Distribution of squash-related injury prevention information may be more successful through media outlets such as through television advertisement breaks, and through SNZ and regional squash or local squash club social media outlets. We recommend that ACC and SNZ collaboratively develop SquashSmart educational material by adapting the NetballSmart resources and making them available on their websites.

3.4.1 Data limitations and future direction

There are some acknowledged limitations within the current research. Data analyses were limited to categories dictated by ACC collection. Injury body sites were limited to isolated areas, otherwise reported as multiple sites, which may have skewed data with some areas possibly under-represented. For example, if a player injured both their knee and ankle in the same injury event, this would either be coded to only ankle or knee body site categories, or as a multiple sites injury without further definition. This is the same with other combined injuries such as neck and shoulder injuries possibly being under-represented in this data collection model. The dataset relies heavily on data entry accuracy, however while cleaning the data during analysis, errors were discovered with some extracted claims being unrelated to squash as a sport (e.g., a squashed finger due to some other event). Squash-related injuries may therefore have been miscategorised into other sports or activities which may also skew results.

Available data did not provide player experience level, playing hours, or participation levels for claimants, limiting data analyses capabilities (e.g., we could not calculate injuries per 1,000 participant hours of exposure to squash play). Future research should evaluate the level of experience for ACC injury reporting to determine if this is an injury risk factor. Improved participation data through SNZ, linked with ACC injury data by player name, would allow for in-depth analysis into injury prevalence within the squash population.

3.5 Conclusions

Injuries resulting from squash are consistently more common in men across all age groups and body sites. Men were injured twice as often as women. Squash players aged 50 to 59 years were injured most frequently, closely followed by 40- to 49-year-olds. Current SNZ grading list data reported 67.3% of competitive players

were men and more than half of all competitive players were over the age of 35. Of all squash-related injuries reported, 93% were soft tissue injuries. Lower body injuries accounted for 50.5% of all reported injuries. An injury rate of between 4,438.78-32,196.16 injuries per 100,000 players was estimated from the available data. Injury prevention strategies targeted at preventing lower limb soft tissue injuries by improving balance and twisting control for men aged 40 years and over, could provide the greatest reduction in squash-related injury risk.

CHAPTER 4: DISCUSSION AND CONCLUSIONS

Squash is a popular racquet sport, originating in England in the 19th century, which has steadily grown in popularity worldwide now being played in over 155 nations (Britannica, 2024). Players are required to perform high-intensity, repetitive and explosive movements within the confined four-walled 62.5m^2 court (Horobeanu et al., 2019; Horsley et al., 2020). Played to 11 or 15 points, best of five games, and games lasting at least seven minutes each, players require sufficient aerobic and anaerobic fitness (James et al., 2022). Due to the close proximity of players within the court, and the nature of the quick change of direction and forceful movements required in order to successfully play the ball, squash is a sport with a moderate to high injury risk (Meyer et al., 2007).

Although continuing to gain in popularity, there is limited squash-related injury literature available within NZ, and squash-related injury prevention literature globally (Horsley et al., 2020). The first aim of this thesis was to systematically review available squash-related injury research published since 2004 to determine the most common injuries sustained in squash and any associated risk factors. The systematic review also reported injury prevention tools or strategies presented in the literature, and the effectiveness of any strategies if indicated.

Within NZ approximately 90,000 New Zealanders play squash annually, with around 12,000 registered graded players (Squash New Zealand, 2012, 2024a). Graded player data suggests squash is more commonly played by adults, with 83.5% of competitive players registered in NZ over 19 years old (Supplementary Table V). Although NZ data suggests increased participation by adults compared to those under 19 years old, studies on adolescent and school-aged squash players are frequently presented in available literature(Horobeanu et al., 2019; Meyer et al., 2007; Sankaravel et al., 2017). Squash-related injury data within NZ is poorly represented within current literature, with one study investigating head and face injuries in 1980 (Clemett & Fairhurst, 1980), and a second study reporting on back injuries published in 1998 (Macfarlane & Shanks, 1998). Given this, an update and investigation into squash-related epidemiological and injury patterns, and the costs of these injuries was undertaken as part of this thesis.

The systematic review consisted of 26 papers that met inclusion criteria. This included 23 epidemiological investigations and three review papers. These publications were not all exclusively investigating squash-related injuries, however, those including squash-related injury data that was able to be discerned from other sports were included. Heterogeneity occurred between study data-gathering strategies, including national

injury surveillance databases, player self-reported questionnaires, and hospital presentations and admissions, for example (Finch, 1997). These differing collection methods influence data available for analyses as studies drawing from hospital emergency department presentations and admissions will be limited to high-severity injuries warranting hospital assessment. This results in skewed findings and an overrepresentation of severe injuries should results be pooled with squash-related injury surveillance data gathered from more broad sources, such as questionnaires administered within a club environment (Finch, 1997). A search for further literature published after 26 July 2024 using the search strategy outlined in Chapter 2 and Supplementary Table I. This produced one further paper investigating upper limb muscle activation in the squash backhand shot (Abuwarda et al., 2024). Ten elite female squash players were recruited for the study and upper limb muscle activation during straight and cross-court backhand shots were documented. The authors found no difference between muscle activation in arm and wrist muscles when players performed a cross-backhand or straight-backhand shot. At the shoulder, increased activity of the anterior deltoid was observed during straight-backhand shots, and increased activity of the posterior deltoid was observed during cross-backhand shots. The authors suggest strengthening muscles assessed within the study may reduce squash-related shoulder injuries among squash players (Abuwarda et al., 2024).

The lower limb was reported as most commonly injured as a result of exposure to squash, either during games or training (Fong et al., 2007; Horobeanu et al., 2019; Horsley et al., 2020; Jhamb & Asundi, 2022; Jhamb & Singh, 2022; Nhan et al., 2018; Sankaravel et al., 2017). This is in agreement with the epidemiological study presented in this paper, where lower limb injuries accounted for more than half (50.5%) of all squash-related injuries lodged with ACC in NZ over the ten-year study period. Current studies into squash-related injury patterns have been small, ranging from single case studies to just under 3,500 in one study that combined squash and racquetball given the similarities of the sports (Nhan et al., 2018). These small participant numbers potentially skewed reporting of injury incidence. However, the epidemiology paper presented in Chapter 3 included 39,949 squash-related injuries which is the largest reported study in current literature, validating the lower limb as the most injurious body site as a result of playing squash.

The characteristics of squash result in an increased risk of players suffering injury. This is due to the physical demands of the game combined with players being in close proximity within a confined space(Jendrusch et al., 2022; Jones et al., 2018; Meyer et al., 2007; Sinclair et al., 2016). Risk of injury is further increased due to the velocity of both the ball and racquet which can reach speeds of 22.km/h and 190km/h respectively (Mazarelo et al., 2024; Tin-Oo & Razali, 2012). As a result, increased exposure to squash increases the risk of both acute and chronic injuries sustained by players (Okhovatian & Ezatolahi, 2009; Rejeb et al., 2017). Player experience and expertise also influences risk of squash-related injury, as those with a better understanding of rules designed to minimise injury as a result of player colliding with the ball, racquet, or opponent likely have a reduced risk of contact injury (Eime, Finch, et al., 2004; Persic et al., 2006).

Although rarely documented within epidemiological studies investigating all squash-related injuries, serious eye injury prevention strategies dominate squash-related injury prevention literature. Seven of the

11 studies meeting systematic review inclusion criteria reported on the use of appropriate protective eyewear to reduce serious squash-related eye injury (Eime, Finch, et al., 2004; Eime, Finch, Owen, et al., 2005; Eime, Finch, Wolfe, et al., 2005; Eime, McCarty, et al., 2005; Jendrusch et al., 2022; Mazarelo et al., 2024; Mishra et al., 2014). Appropriate protective eyewear is able to protect against serious eye injury, however, use of this injury prevention tool is low among squash players (Eime, McCarty, et al., 2005). The use of mouthguards has also been suggested to reduce squash-related dental injuries (Persic et al., 2006; Tin-Oo & Razali, 2012), although dental injuries are rarely reported in squash-related injury literature.

Only two studies were identified investigating lower limb injury prevention in squash (Sinclair et al., 2016; Sinclair et al., 2017). These authors reported on the use of appropriate footwear to reduce ankle and knee loading, advising the use of squash-specific footwear rather than minimalist shoes. As lower limb injuries account for the majority of squash-related injuries in literature, it is warranted that further investigation into an appropriate injury prevention strategy or tool is undertaken.

The cost of squash-related injuries has not been discussed in literature. This thesis aimed to investigate the burden of squash-related injury on NZ through ACC data. Over the study period of 2012 to 2021, squash-related injuries cost NZ a total of NZ$37,740,867. Men aged 40 to 59 years old accounted for over 40% of this cost. The knee, ankle, and shoulder were the costliest injuries with a total of NZ$10,382,433, NZ$8,087,284, and NZ$5,410,357 respectively.

The epidemiology study presented in Chapter 3 provided insight into squash-related injuries within NZ, and the cost of these injuries as reported by ACC. This research provided novel findings into squash-related mechanism of injury, which is poorly reported on in current literature. Due to ACC claims recording how injuries occurred rather than purely providing a diagnosis, it is now documented that over a quarter (27.3% of all claims over the study period) of squash-related injuries within NZ are as a result of loss of balance/personal control, and approximately one in five squash-related injuries resulting from twisting movements (22.4% of all claims over the study period).

The findings presented in Chapter 3 and the systematic review in Chapter 2 provided valuable information to guide future research into squash-related injury and the development of injury prevention tools. Lower limb injuries are commonly occurring in squash, and further attention to strategies to reduce these injuries is necessary. The epidemiology paper in Chapter 3 provides novel information on squash-related mechanism of injury and burden of cost. Based on these findings and previous literature as indicated in the systematic review in Chapter 2, in order to provide the greatest reduction in squash-related injury risk and burden of cost, future research should be aimed at lower limb injury prevention strategies, with consideration to improving player balance and proprioception or spatial awareness. Due to the nature of squash, unlike team sports where injury prevention strategies incorporating exercise-based intervention can be conducted at weekly trainings, the onus is on the individual player to engage independently. In the case of protective eyewear, it was shown infographics and posters placed within clubs improved player uptake. This strategy could be utilised in the event of an injury prevention strategy such as the warm-ups provided by RugbySmart,

with infographic propaganda being disseminated by the governing squash bodies to clubs, and videos of exercises to improve balance and proprioception being played through relevant social media outlets. This would increase exposure to these injury prevention tools and possibly an increase in participation, as demonstrated by Eime, Finch, Wolfe, et al. (2005) where player behaviour toward adopting the use of appropriate protective eyewear through the use of stickers and posters.

4.1 Thesis limitations

Research presented within this thesis was not without limitations. The systematic review in Chapter 2 excluded all papers not presented in the English language. This may have resulted in the omission of novel or conflicting findings that could have influenced the results of the review. Studies resulting from the search strategy were varied in methodology which impacted on the ability to make direct comparisons between findings. The differing study methodologies and data collection strategies impacts on injuries reported where those using hospital data were limited to more serious injury warranting hospital assessment and treatment. In comparison, studies gathering data through surveys at sporting establishments were able to capture injuries ranging from minor to severe as players within the same club may have suffered a sprain requiring little to no intervention, through to serious injury requiring surgery for example. Identified and included studies were also of varying populations, limiting the generalisability of findings such as those studies only investigating elite and adolescent squash players.

Limitations to the data available within the NZ epidemiology study presented in Chapter 3 resulted in the inability to comment on claimant level of ability, or exposure to squash. This was dictated by ACC data collection categories. Within the ACC data, multiple injuries under the same claim were not separated by individual body site. For example, if a player injured their shoulder and ankle in the same incident, it would be coded as “multiple sites”. This may have skewed data, possibly under or over representing some body sites. This data is also limited by the need to rely on data entry accuracy, as when cleaning the data entry errors were discovered with injuries unrelated to the sport squash were included, such as in the event of someone becoming squashed under an object. Squash-related injuries may also have been miscoded and therefore findings may be skewed.

4.2 Conclusions

This thesis has presented two research papers and answered four research questions. The first paper provided insight into current squash-related injury literature pertaining to common injuries, risk factors, and injury prevention strategies. The second paper investigated squash-related injuries within NZ, including epidemiological and injury patterns, and the cost of these injuries to NZ. Findings from these studies indicated a need for injury prevention strategies targeting lower limb injuries within squash. Based on the epidemiology paper presented, injury prevention strategies would provide the greatest reduction in squash-related injuries

when aimed at improving player balance and spatial awareness. Future studies should focus on the development and evaluation of an exercise-based injury prevention programme, such as those provided by ACC. Unlike the ACC SportSmart programmes currently available for team sports, an injury prevention programme for squash will need to be promoted through clubs and social media as squash is an individual sport. Future research should aim to develop and evaluate injury prevention strategies with the aim to reduce squash-related injury. It is hoped the papers prepared within this thesis will assist in this development through collecting the current knowledge available, and providing novel information on mechanism and costs of squash-related injury.

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APPENDICES

Appendix A – Prospero registration

PROSPERO
International prospective register of systematic reviews

NHS
National Institute for Health Research

UNIVERSITY of York
Centre for Reviews and Dissemination

Systematic review

*Fields that have an **asterisk (*)** next to them means that they **must be answered. Word limits** are provided for each section. You will be unable to submit the form if the word limits are exceeded for any section. Registrant means the person filling out the form.*

1. * Review title.

Give the title of the review in English

Squash-related injuries: A systematic literature review

2. Original language title.

For reviews in languages other than English, give the title in the original language. This will be displayed with the English language title.

3. * Anticipated or actual start date.

Give the date the systematic review started or is expected to start.

29/01/2024

4. * Anticipated completion date. [1 change]

Give the date by which the review is expected to be completed.

30/08/2024

5. * Stage of review at time of this submission. [1 change]

This field uses answers to initial screening questions. It cannot be edited until after registration.

Tick the boxes to show which review tasks have been started and which have been completed.

Update this field each time any amendments are made to a published record.

The review has not yet started: No

Review stage	Started	Completed
Preliminary searches	Yes	Yes
Piloting of the study selection process	Yes	Yes
Formal screening of search results against eligibility criteria	Yes	Yes
Data extraction	Yes	Yes
Risk of bias (quality) assessment	Yes	Yes
Data analysis	Yes	No

Provide any other relevant information about the stage of the review here.

6. * Named contact.

The named contact is the guarantor for the accuracy of the information in the register record. This may be any member of the review team.

Amy Honeyfield

Email salutation (e.g. "Dr Smith" or "Joanne") for correspondence:
Mrs Honeyfield

7. * Named contact email.

Give the electronic email address of the named contact.

gjq8296@autuni.ac.nz

8. Named contact address

PLEASE NOTE this information will be published in the PROSPERO record so please do not enter private information, i.e. personal home address

Give the full institutional/organisational postal address for the named contact.

Sports Performance Research Institute New Zealand

Faculty of Health and Environmental Sciences

Auckland University of Technology

Private Bag 92006

Auckland 1142

New Zealand

9. Named contact phone number.

Give the telephone number for the named contact, including international dialling code.

+64273606744

10. * Organisational affiliation of the review.

Full title of the organisational affiliations for this review and website address if available. This field may be completed as 'None' if the review is not affiliated to any organisation.

Sports Performance Research Institute New Zealand (SPRINZ), Auckland University of Technology

Organisation web address:

11. * Review team members and their organisational affiliations. [1 change]

Give the personal details and the organisational affiliations of each member of the review team. Affiliation refers to groups or organisations to which review team members belong.
NOTE: email and country now MUST be entered for each person, unless you are amending a published record. PLEASE USE AN INSTITUTIONAL EMAIL ADDRESS IF POSSIBLE.

Mrs Amy Honeyfield. Sports Performance Research Institute New Zealand (SPRINZ), Auckland University of Technology

Professor Patria Hume. Sports Performance Research Institute New Zealand (SPRINZ), Auckland University of Technology

Gaye Bryham. Sports Performance Research Institute New Zealand (SPRINZ), Auckland University of Technology

12. * Funding sources/sponsors.

Details of the individuals, organizations, groups, companies or other legal entities who have funded or sponsored the review.

Not applicable

Grant number(s)
State the funder, grant or award number and the date of award

13. * Conflicts of interest.

List actual or perceived conflicts of interest (financial or academic).

None

14. Collaborators.

Give the name and affiliation of any individuals or organisations who are working on the review but who are not listed as review team members. **NOTE: email and country must be completed for each person, unless you are amending a published record.**

15. * Review question.

State the review question(s) clearly and precisely. It may be appropriate to break very broad questions down into a series of related more specific questions. Questions may be framed or refined using PI(E)COS or similar where relevant.

What injuries are most common as a result of the sport of squash? Are there any risk factors identified contributing to squash-related injuries? Have any injury prevention strategies been implemented and if so is there any evidence of success?

16. * Searches.

State the sources that will be searched (e.g. Medline). Give the search dates, and any restrictions (e.g. language or publication date). Do NOT enter the full search strategy (it may be provided as a link or attachment below.)

Databases to be searched are EBSCO Health Databases (CINAHL Complete, Dentistry & Oral Sciences Source, MEDLINE, SPORTDiscus with Full Text).

Reference lists of eligible papers will also be searched for eligible articles.

Search dates will be 2004 - present.

Eligible papers must be available in English language and full text.

Searches will be re-run before final analyses are completed to ensure all current eligible articles are included.

17. URL to search strategy.

Upload a file with your search strategy, or an example of a search strategy for a specific database, (including the keywords) in pdf or word format. In doing so you are consenting to the file being made publicly accessible.

Or provide a URL or link to the strategy. Do NOT provide links to your search **results**.

Do not make this file publicly available until the review is complete

18. * Condition or domain being studied.

Give a short description of the disease, condition or healthcare domain being studied in your systematic review.

Injuries sustained as a result of the sport of squash.

19. * Participants/population.

Specify the participants or populations being studied in the review. The preferred format includes details of both inclusion and exclusion criteria.

Inclusion: Squash players globally.
Exclusion: All other sports.

20. * Intervention(s), exposure(s).

Give full and clear descriptions or definitions of the interventions or the exposures to be reviewed. The preferred format includes details of both inclusion and exclusion criteria.

Playing or training for squash.

21. * Comparator(s)/control.

Where relevant, give details of the alternatives against which the intervention/exposure will be compared (e.g. another intervention or a non-exposed control group). The preferred format includes details of both inclusion and exclusion criteria.

Not applicable

22. * Types of study to be included.

Give details of the study designs (e.g. RCT) that are eligible for inclusion in the review. The preferred format includes both inclusion and exclusion criteria. If there are no restrictions on the types of study, this should be stated.

All study designs will be eligible for inclusion in this review. No restrictions on study type.

23. Context.

Give summary details of the setting or other relevant characteristics, which help define the inclusion or exclusion criteria.

24. * Main outcome(s).

Give the pre-specified main (most important) outcomes of the review, including details of how the outcome is defined and measured and when these measurement are made, if these are part of the review inclusion criteria.

Injuries as a result of squash, participant characteristics and risk factors that may influence likelihood of a squash-related injury.
If an injury prevention strategy has been implemented, has there been a reduction in squash-related injuries documented as a result of the strategy.

Measures of effect

25. * Additional outcome(s).

List the pre-specified additional outcomes of the review, with a similar level of detail to that required for main outcomes. Where there are no additional outcomes please state ‘None’ or ‘Not applicable’ as appropriate to the review

Not applicable

Measures of effect

26. * Data extraction (selection and coding).

Describe how studies will be selected for inclusion. State what data will be extracted or obtained. State how this will be done and recorded.

Study selection: one individual will search and select studies for inclusion in the review.
Data extraction: studies will be saved to Endnote which will also be used to remove duplicates after the initial search.
Author/Date, Participant population and number, injuries reported from squash, if any injury prevention strategies are suggested or implemented, (if a strategy implemented, any information on this and it's effectiveness) will be extracted from articles into a Microsoft Excel spreadsheet by one individual

27. * Risk of bias (quality) assessment.

State which characteristics of the studies will be assessed and/or any formal risk of bias/quality assessment tools that will be used.

All articles will be screened for quality/bias using the relevant CASP tool for each study type.
This information will be entered into a Microsoft Excel spreadsheet.

28. * Strategy for data synthesis.

Describe the methods you plan to use to synthesise data. This **must not be generic text** but should be **specific to your review** and describe how the proposed approach will be applied to your data.
If meta-analysis is planned, describe the models to be used, methods to explore statistical heterogeneity, and software package to be used.

Data will be synthesised through a narrative summary as there will likely be multiple study types and reporting designs to synthesise for this review. This allows for all articles found to be included in the summary and the quality of studies to be further considered within the review. As all squash injury research globally is being included there will likely be differing methods of data collection and analysis, a narrative summary will allow this review to interpret and summarise all results available.

29. * Analysis of subgroups or subsets.

State any planned investigation of 'subgroups'. Be clear and specific about which type of study or participant will be included in each group or covariate investigated. State the planned analytic approach.

Where studies have provided information on participant demographics, such as sex and age, or training hours or participants etc, these subgroups will be analysed to determine any risk factors evident for squash-related injuries.

30. * Type and method of review.

Select the type of review, review method and health area from the lists below.

Type of review

Cost effectiveness	No
Diagnostic	No
Epidemiologic	No
Individual patient data (IPD) meta-analysis	No
Intervention	No
Living systematic review	No
Meta-analysis	No
Methodology	No
Narrative synthesis	No
Network meta-analysis	No
Pre-clinical	No
Prevention	No
Prognostic	No
Prospective meta-analysis (PMA)	No
Review of reviews	No

Service delivery	No
Synthesis of qualitative studies	No
Systematic review	Yes
Other	No

Health area of the review

Alcohol/substance misuse/abuse	No
Blood and immune system	No
Cancer	No
Cardiovascular	No
Care of the elderly	No
Child health	No
Complementary therapies	No
COVID-19	No
Crime and justice	No
Dental	No
Digestive system	No
Ear, nose and throat	No
Education	No
Endocrine and metabolic disorders	No
Eye disorders	No
General interest	No
Genetics	No
Health inequalities/health equity	No
Infections and infestations	No
International development	No
Mental health and behavioural conditions	No
Musculoskeletal	Yes
Neurological	No
Nursing	No

Obstetrics and gynaecology	No
Oral health	No
Palliative care	No
Perioperative care	No
Physiotherapy	Yes
Pregnancy and childbirth	No
Public health (including social determinants of health)	No
Rehabilitation	No
Respiratory disorders	No
Service delivery	No
Skin disorders	No
Social care	No
Surgery	No
Tropical Medicine	No
Urological	No
Wounds, injuries and accidents	Yes
Violence and abuse	No

31. Language.

Select each language individually to add it to the list below, use the bin icon to remove any added in error.

English

There is not an English language summary

32. * Country.

Select the country in which the review is being carried out. For multi-national collaborations select all the countries involved.

New Zealand

33. Other registration details.

Name any other organisation where the systematic review title or protocol is registered (e.g. Campbell, or The Joanna Briggs Institute) together with any unique identification number assigned by them.
If extracted data will be stored and made available through a repository such as the Systematic Review Data Repository (SRDR), details and a link should be included here. If none, leave blank.

34. Reference and/or URL for published protocol.

If the protocol for this review is published provide details (authors, title and journal details, preferably in Vancouver format)

No I do not make this file publicly available until the review is complete

35. Dissemination plans.

Do you intend to publish the review on completion?

Yes

This review will be used towards a thesis in the Master of Health Science programme, as well as being submitted for publication in a relevant journal.

36. Keywords.

Give words or phrases that best describe the review. Separate keywords with a semicolon or new line. Keywords help PROSPERO users find your review (keywords do not appear in the public record but are included in searches). Be as specific and precise as possible. Avoid acronyms and abbreviations unless these are in wide use.

Squash-related injury; racquet sport; injury; injury prevention

37. Details of any existing review of the same topic by the same authors.

If you are registering an update of an existing review give details of the earlier versions and include a full bibliographic reference, if available.

38. * Current review status. [1 change]

Update review status when the review is completed and when it is published.
New registrations must be ongoing so this field is not editable for initial submission.

Review_Completed_not_published

39. Any additional information.

Provide any other information relevant to the registration of this review.

40. Details of final report/publication(s) or preprints if available.

Leave empty until publication details are available OR you have a link to a preprint (NOTE: this field is not editable for initial submission).
List authors, title and journal details preferably in Vancouver format.

Appendix B – ACC ethics

THIS CONFIDENTIALITY AGREEMENT is made the 5th day of SEPTEMBER 2022

BETWEEN ACCIDENT COMPENSATION CORPORATION ("ACC")

AND Patria Anne Hume of AUCKLAND UNIVERSITY OF TECHNOLOGY (AUT) ("the Researcher")

BACKGROUND:

1. The Researcher has applied to ACC for access to certain ACC data (as described in Appendix 1) (the **ACC Data**). ACC has agreed that the Researcher will have access to the ACC Data in accordance with this Agreement for the purposes of the research described in Appendix 2 (**Research**).

2. The ACC Data contains information which is confidential to ACC and/or contains personal information about individuals. In order to protect the value and confidentiality of the ACC Data the parties have agreed to enter into this Agreement. If the ACC Data contains health information, the Researcher will only have access to it if ACC's Ethics Panel has advised that the disclosure should be approved and the ACC Head of Privacy has given final approval.

ACC AND THE RESEARCHER AGREE as follows:

1. **Confidentiality**: The Researcher and its employees and agents shall keep confidential all ACC Data (whether in oral, written, visual or electronic form) provided by ACC for the purpose of the Research.

2. **Use**: The Researcher shall only use the ACC Data for the purpose of the Research. The Researcher also agrees that:

    2.1. when using the ACC Data, it will take into account any guidance, qualifications or warnings that ACC may provide (for example, as to error tolerance or data quality);
    2.2. it will not use the ACC Data, either alone or in conjunction with other data, for the purpose of identifying or re-identifying particular individuals, whānau or households; and
    2.3. it will not use or interpret the ACC Data in a manner that unjustifiably and adversely discriminates against one or more groups.

3. **Access to ACC Data**: The Researcher will only allow the following persons to have access to the ACC Data:

    3.1. employees of the Researcher who are directly involved in the Research; and
    3.2. persons who are not employees of the Researcher but who are directly involved in the Research (including students),

    as long as every such person commits to a confidentiality agreement or undertaking in accordance with clause 4.

4. **Those with access to ACC Data to be subject to confidentiality requirements**: The Researcher shall ensure that every person who has access to the ACC Data will enter into a confidentiality agreement or give a confidentiality undertaking, in a form acceptable to ACC, to maintain the confidentiality of the ACC Data on terms equivalent to the terms of this Agreement. Breach of any such confidentiality agreement or undertaking shall be deemed to be a breach by the Researcher.

5. **Requests for ACC Data**: If the Researcher receives a request for the ACC Data, the Researcher will advise ACC by the close of the next working day and follow ACC's instructions about how to respond to the request (such instructions to be in accordance with the law).

6. **Disclosure**: The Researcher will not disclose any of the ACC Data without ACC's written consent, unless:

    6.1. it is required by law to disclose that information; or
    6.2. that information is publicly available.

7. **Compliance with law**: The Researcher and its employees and agents will comply with the Privacy Act 2020 (including, where applicable, the Health Information Privacy Code 2020 (**HIPC**)) in respect of the ACC Data.

8. **No reliance on IPP/HIPC exceptions**: To avoid doubt, the Researcher shall not:

    8.1. use any personal information or health information in reliance on an exception in the Privacy Act's information privacy principle 10 or the HIPC's rule 10; or
    8.2. disclose any personal information or health information in reliance on an exception in information privacy principle 11 or the HIPC's rule 11,

    without ACC's prior written consent.

9. **No publication involving identified or identifiable individuals**: Without limiting clauses 6-8, the Researcher agrees that no ACC Data, and no research findings or other outputs, will be published in a form where an individual is, or could reasonably be expected to be, identified or identifiable.

10. **Secure storage and transfer**: The Researcher and its employees and agents will:

    10.1. store the ACC Data in compliance with Information Privacy Principle 5 of the Privacy Act 2020 or rule 5 of the HIPC (as applicable); and
    10.2. ensure that any transfer of the ACC Data, between persons authorised under this Agreement to see the ACC Data for the purposes of the Research, is effected by secure means.

11. **Intellectual property**: All rights, title and interest in any and all information, data, research findings, reports and other results arising from the Research from the use of the ACC Data (other than the ACC Data itself) automatically vest in the Researcher from the date of this Agreement or otherwise from the date of creation. If ACC requests, the Researcher will:

    11.1. grant to ACC a licence to use the Research for ACC's internal purposes (the licence will be irrevocable and royalty-free); and
    11.2. transfer a copy of the Research to ACC if ACC does already have it.

12. **Retention and destruction**: The Researcher will destroy the ACC Data as soon as it is no longer required for the purposes for which it may lawfully be used, in accordance with information privacy principle 9 or the HIPC's rule 9 (as applicable). If the Researcher is subject to the Public Records Act 2005, this clause 12 is subject to any obligation in that Act to the contrary, but only until such time as the ACC Data may, in accordance with that Act, be disposed of.

13. **Pre-publication copy of research to ACC for comment**: Before publication of any research using the ACC Data, the Researcher will provide a copy of the research to ACC for review and give ACC a reasonable opportunity to consider the research and provide comment. If ACC considers that the research contains errors or misrepresentations, the Researcher will either amend the research or, at ACC's request, include a statement from ACC.

SIGNED by

Aisling Risdon

Aisling W Risdon

....

Aisling Risdon, Head of Privacy Signature

on behalf of the
ACCIDENT COMPENSATION CORPORATION

Patria Hume

02/09/2022

....

Patria Anne Hume Signature

on behalf of the Auckland University of Technology

APPENDIX 1 – DATA FIELD REQUESTS AND DESCRIPTION OF ACC DATA

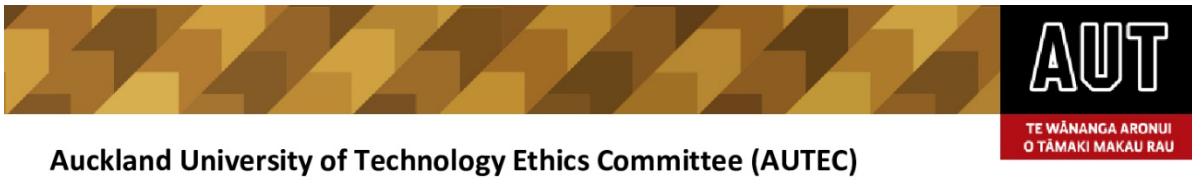
Research Questions	Primary outcomes	Secondary outcomes	Variables
Patient information:	Patient		Dummy claim number ID
			Dummy person ID
	Sex		Sex
	Ethnicity		Ethnicity
	Age		Date of birth
	Time and date of injury		Date of injury
What are the types, mechanisms and causes of squash injuries in New Zealanders?	Types of squash related injuries		Sport-related indicator
			Diagnosis group & diagnosis
			Injury body site
			Injury body side
	Causes of squash related injuries		Work accident indicator
			Scene of accident
			Cause of accident
			Activity prior to accident
			Cause of accident
			Contact when injured
			Accident description
What are the financial costs associated with each injury?	Financial cost for ACC	Cost of treatment until discharged from service ?	Service in ACC claim
			ACC cover cost per service
	Financial cost for patient	Cost of treatment until discharged from service	Cost of Services/treatments provided by ACC
			Number of consultations/treatments
		Travel cost	Patient's residential area unit/district/city/region
			Service area unit/district/city/region
			Transportation cost

APPENDIX 2 - DESCRIPTION OF RESEARCH

This research will describe the incidence, severity, costs, causes, and mechanisms of squash related injuries in New Zealand. Deidentified ACC data between January 2012 and December 2021 will be analysed to identify these injuries and direct future research implementing an injury prevention intervention.

The table in appendix 1 illustrates how the requested ACC data variables will be used to answer the related research questions in this study.

Appendix C – AUTEC ethics



Auckland University of Technology Ethics Committee (AUTEC)

Auckland University of Technology
D-88, Private Bag 92006, Auckland 1142, NZ
T: +64 9 921 9999 ext. 8316
E: ethics@aut.ac.nz
www.aut.ac.nz/researchethics

15 November 2022

Patria Hume
Faculty of Health and Environmental Sciences

Dear Patria

Re Ethics Application: **22/287 Epidemiology of squash related injuries in New Zealand: A review of ten years of Accident Compensation Corporation moderate to severe claims and costs.**

Thank you for providing evidence as requested, which satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC).

Your ethics application has been approved for three years until 15 November 2025.

Standard Conditions of Approval

1. The research is to be undertaken in accordance with the Auckland University of Technology Code of Conduct for Research and as approved by AUTEC in this application.
2. A progress report is due annually on the anniversary of the approval date, using the EA2 form.
3. A final report is due at the expiration of the approval period, or, upon completion of project, using the EA3 form.
4. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form.
5. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
6. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.
7. It is your responsibility to ensure that the spelling and grammar of documents being provided to participants or external organisations is of a high standard and that all the dates on the documents are updated.
8. AUTEC grants ethical approval only. You are responsible for obtaining management approval for access for your research from any institution or organisation at which your research is being conducted and you need to meet all ethical, legal, public health, and locality obligations or requirements for the jurisdictions in which the research is being undertaken.

Please quote the application number and title on all future correspondence related to this project.

For any enquiries please contact ethics@aut.ac.nz. The forms mentioned above are available online through http://www.aut.ac.nz/research/researchethics

(This is a computer-generated letter for which no signature is required)

The AUTEC Secretariat
Auckland University of Technology Ethics Committee

Cc: gjq8296@autuni.ac.nz; gaye.bryham@aut.ac.nz

Appendix D – Chapter 2 supplementary tables

Supplementary Table I Search strategy

EBSCOHealth Databases **MEDLINE, CINAHL Complete, Dentistry & Oral Science Sources, SPORTDiscus with Full Text**		
Search Terms	**Search Options**	**Results**
((Squash Sport OR Squash) AND (Injury OR injuries OR accident OR trauma))	Expanders – apply related words; apply equivalent subjects Search modes – Proximity	818

Scopus	
Search Terms	**Results**
Your query : ((TITLE-ABS-KEY(Squash sport OR Squash) AND TITLE-ABS-KEY(injury OR injuries OR accident OR trauma)))	367

Google Scholar		
Search Terms	**Limiters**	**Results**
"squash", +injury, +injuries, +accident, +trauma	-vegetable, -cytology, -smear, -book 2004-present	438

Supplementary Table II Four JBI checklists used in the analyses: Cross Sectional study checklist; Case Report study checklist; Systematic Review checklist; and the Cohort study checklist.

JBI Critical Appraisal Checklist for analytical cross-sectional studies

Reviewer_____Date_____

Author_____Year_____ Record Number_____

	Yes	No	Unclear	Not applicable
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?	□	□	□	□

Overall appraisal: Include □ Exclude □ Seek further info □

Comments (Including reason for exclusion)

_____

_____

_____

JBI Critical Appraisal Checklist for case reports

Reviewer_____Date_____

Author_____Year_____ Record Number_____

	Yes	No	Unclear	Not applicable
1. Were patient's demographic characteristics clearly described?	□	□	□	□
2. Was the patient's history clearly described and presented as a timeline?	□	□	□	□
3. Was the current clinical condition of the patient on presentation clearly described?	□	□	□	□
4. Were diagnostic tests or assessment methods and the results clearly described?	□	□	□	□
5. Was the intervention(s) or treatment procedure(s) clearly described?	□	□	□	□
6. Was the post-intervention clinical condition clearly described?	□	□	□	□
7. Were adverse events (harms) or unanticipated events identified and described?	□	□	□	□
8. Does the case report provide takeaway lessons?	□	□	□	□

Overall appraisal: Include □ Exclude □ Seek further info □

Comments (Including reason for exclusion)

_____
_____
_____
_____

JBI Critical Appraisal Checklist for systematic reviews and research syntheses

Reviewer_____ Date_____

Author_____Year_____ Record Number_____

	Yes	No	Unclear	Not applicable
1. Is the review question clearly and explicitly stated?	□	□	□	□
2. Were the inclusion criteria appropriate for the review question?	□	□	□	□
3. Was the search strategy appropriate?	□	□	□	□
4. Were the sources and resources used to search for studies adequate?	□	□	□	□
5. Were the criteria for appraising studies appropriate?	□	□	□	□
6. Was critical appraisal conducted by two or more reviewers independently?	□	□	□	□
7. Were there methods to minimize errors in data extraction?	□	□	□	□
8. Were the methods used to combine studies appropriate?	□	□	□	□
9. Was the likelihood of publication bias assessed?	□	□	□	□
10. Were recommendations for policy and/or practice supported by the reported data?	□	□	□	□
11. Were the specific directives for new research appropriate?	□	□	□	□

Overall appraisal: Include □ Exclude □ Seek further info □

Comments (Including reason for exclusion)

_____

_____

_____

JBI Critical Appraisal Checklist for cohort studies

Reviewer_____Date_____

Author_____Year_____ Record Number_____

	Yes	No	Unclear	Not applicable
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?	□	□	□	□

Overall appraisal: Include □ Exclude □ Seek further info □

Comments (Including reason for exclusion)

Supplementary Table III Critical appraisal of included studies using JBI critical appraisal tools.

Critical appraisal of cross-sectional studies using JBI cross-sectional appraisal tool

Author/s (year)	1	2	3	4	5	6	7	8	Outcome†
Akl, A. R., Hassan, A., Elgizawy, H., & Tilp, M. (2021)(Akl et al., 2021)	✓	✓	✓	✓	✓	?	✓	✓	87.5%; Low
Çetinkaya, E. (2018)(Çetinkaya, 2018)	✓	✓	✓	?	✓	✓	✓	✓	87.5%; Low
Eime, R., Finch, C., Owen, N., Gifford, S., & Vear, P. (2004)(Eime, Finch, et al., 2004)	✓	✓	✓	?	✓	?	✓	✓	75%; Low
Eime, R., Finch, C., Owen, N., & McCarty, C. (2005)(Eime, Finch, Owen, et al., 2005)	✓	✓	✓	?	✓	✓	?	?	62.5%; Moderate
Eime, R., Finch, C., Wolfe, R., Owen, N., & McCarty, C. (2005)(Eime, Finch, Wolfe, et al., 2005)	✓	✓	✓	?	✓	?	✓	✓	75%; Low
Eime, R., McCarty, C., Finch, C. F., & Owen, N. (2005)(Eime, McCarty, et al., 2005)	✓	✓	✓	✓	✓	?	✓	✓	87.5%; Low
Horsley, I. G., O'Donnell, V., & Leeder, J. (2020)(Horsley et al., 2020)	✓	✓	?	✓	✓	?	✓	✓	75%; Low
Jendrusch, G., Henke, T., Schnell, D., & Platen, P. (2022)(Jendrusch et al., 2022)	✓	✓	?	?	✓	?	✓	✓	62.5%; Moderate
Jhamb, D., & Asundi, J. (2022)(Jhamb & Asundi, 2022)	✓	✓	?	?	✓	?	✓	?	50%; Moderate
Jhamb, D., & Singh, S. (2022)(Jhamb & Singh, 2022)	✓	✓	?	?	✓	?	✓	?	50%; Moderate
Meyer, L., van Niekerk, L., Prinsloo, E., Steenkamp, M., & Louw, Q. (2007)(Meyer et al., 2007)	✓	✓	?	✓	✓	✓	✓	✓	87.5%; Low
Nhan, D. T., Klyce, W., & Lee, R. J. (2018)(Nhan et al., 2018)	✓	✓	✓	?	✓	✓	✓	✓	87.5%; Low
Okhovatian, F., & Ezatolahi, A. H. (2009)(Okhovatian & Ezatolahi, 2009)	✓	✓	?	✓	✓	✓	?	?	62.5%; Moderate
Persic, R., Pohl, Y., & Filippi, A. (2006)(Persic et al., 2006)	✓	✓	✓	✓	✓	✓	✓	✓	100%; Low
Sankaravel, M., Lee, A. C., Mondam, S., & Low, J. F. L. (2017)(Sankaravel et al., 2017)	✓	✓	?	✓	✓	?	✓	✓	75%; Low
Sinclair, J., Bottoms, L., Taylor, P. J., & Mahmood, K. (2016)(Sinclair et al., 2016)	?	✓	✓	✓	×	?	✓	✓	62.5%; Moderate
Sinclair, J., Bottoms, L., Taylor, P. J., & Mahmood, K. (2017)(Sinclair et al., 2017)	?	✓	✓	✓	×	?	✓	✓	62.5%; Moderate
Tin-Oo, M. M., & Razali, R. (2012)(Tin-Oo & Razali, 2012)	✓	✓	✓	✓	✓	✓	✓	✓	100%; Low

Critical appraisal of case reports studies using JBI case report appraisal tool

Author/s (year)	1	2	3	4	5	6	7	8	Outcome†
Atik, A., Krilis, M., & Parker, G. (2012)(Atik et al., 2012)	?	?	✓	✓	✓	✓		✓	71.4%; Low
Mishra, A., Baranwal, V. K., Patra, V. K., & Bhargava, N. (2014)(Mishra et al., 2014)	×	✓	✓	✓	✓	✓	✓	✓	87.5%; Low
Patel, N. D., & Trehan, R. K. (2007)(Patel & Trehan, 2007)	✓	✓	✓	✓	✓	?		✓	85.7%; Low

Critical appraisal of reviews studies using JBI systematic review and research syntheses appraisal tool

Author/s (year)	1	2	3	4	5	6	7	8	9	10	11	Outcome†

Fong, D. T., Hong, Y., Chan, L., Yung, P. S., & Chan, K. M. (2007)(Fong et al., 2007)	✓	✓	✓	✓	×	×	?	✓	?	✓	✓	63.6%; Moderate
Jones, T. W., Williams, B. K., Kilgallen, C., Horobeanu, C., Shillabeer, B. C., Murray, A., & Cardinale, M. (2018)(Jones et al., 2018)	✓									✓	✓	100%; Low
Mazarelo, J. F. D., Winter, S. L., & Fong, D. T. P. (2024)(Mazarelo et al., 2024)	✓	✓	✓	?	✓	×	?	✓	✓	✓	✓	72.7%; Low

Critical appraisal of cohort studies using JBI cohort appraisal tool

Author/s (year)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Outcome†**
Horobeanu, C., Johnson, A., & Pullinger, S. A. (2019)(Horobeanu et al., 2019)			✓	✓	?	✓	✓	✓	✓	?	✓	77.8%; Low
Rejeb, A., Johnson, A., Vaeyens, R., Horobeanu, C., Farooq, A., & Witvrouw, E. (2017)(Rejeb et al., 2017)			✓	✓	✓	✓	✓	✓	✓	✓	✓	100%; Low

Key:

	✓	Yes	×	No
	?	Unclear		Not applicable

† Outcome based on % yes to applicable questions, ≤49% High risk of bias, 50-69% Moderate risk of bias, ≥70% Low risk of bias (Goplen et al., 2019; Melo et al., 2018)

Appendix E – Chapter 3 supplementary tables

Supplementary Table IV Claim numbers by year.

Year	Number of claims	% total claims
2012	4,093	10.2
2013	4,301	10.8
2014	4,245	10.6
2015	4,237	10.6
2016	4,224	10.6
2017	4,001	10.0
2018	4,182	10.5
2019	4,134	10.3
2020	3,243	8.1
2021	3,289	8.2
Total	39,949	100.0

Supplementary Table V Squash New Zealand grading list by age category and sex.

Age category	Number of graded players	% total graded players	Male graded players	% male graded of all players	Female graded players	% female graded players
Junior (under 19 years)	2,050	16.5	1,445	11.6	605	4.9
Senior (19 to 34 years)	3,233	26.1	2,083	16.8	1,150	9.3
Master (over 35 years)	7,125	57.4	4,828	38.9	2.297	18.5
Total	12,408	100.0	8,356	67.3	4,051	32.7

Supplementary Table VI Claim numbers by region.

Geographical region	Number of claims	% total claims	% population recorded in 2018 census
Northland	1,406	3.5	3.8
Auckland	10,427	26.1	33.4
Waikato	5,436	13.6	9.7
Bay of Plenty	3,754	9.4	6.6
Gisborne	279	0.7	1.0
Hawkes Bay	1,863	4.7	3.5
Taranaki	1,109	2.8	2.5
Manawatu	1,905	4.7	5.1
Wellington	3,867	9.7	10.8
Tasman	437	1.1	1.1
Nelson	311	0.8	1.1
Marlborough	329	0.8	1.0
Canterbury	4,635	11.6	12.8
West Coast	196	0.5	0.7
Otago	2,581	6.5	4.8
Southland	1,385	3.4	2.1
Other	29	0.1	-
Total	39,949	100.0	100.0