Injury Risk Factors and their Priority for Mitigation in Women's Netball: A Systematic Review and Delphi Consensus

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Abstract

This study aimed to establish consensus on injury risk factors in netball via a combined systematic review and Delphi method approach. A systematic search of databases (PubMed, Scopus, MEDLINE, SPORTDiscus, CINAHL) was conducted from inception until June 2023. Twenty-four risk factors were extracted from 17 studies and combined with a three-round Delphi approach to achieve consensus. In round-one, experts listed perceived risk factors for injury in netball which were combined with the risk factors identified via the systematic review. In round-two and round-three, experts rated their level of agreement with each risk factor on a 5-point Likert scale (1-strongly disagree to 5-strongly agree). Consensus was defined as ≥80% agreement (with <10% in disagreement). In round-three, experts also rated the priority for mitigating the risk factor (1-very low to 5-very high). Nineteen experts participated in round-one and round-two, and sixteen participated in round-three (response rate 84%). One-hundred and nine risk factors for injury were identified by the systematic review and experts combined. Sixty-one risk factors reached consensus, categorised into five groups: 'individual characteristics' (n=22), 'lifestyle' (n=11), 'training and competition' (n=14), 'sport science and medical provision' (n=6) and 'facilities and equipment' (n=8). 'Poor landing technique/mechanics' had a median (interquartile range) mitigation priority rating of 5(1), while all others had median ratings of 3-4.5. This study identifies a range of risk factors for injury, provides focus areas for injury prevention, and highlights the importance of a multi-disciplinary approach to injury mitigation in netball.

Key points box:

- The systematic review identified 24 risk factors (19 intrinsic and five extrinsic, 19 modifiable and five non-modifiable) for injury in women's netball from the 17 included studies. Best evidence synthesis found eight with moderate, six with limited and ten with conflicting evidence.
- A greater focus on high quality research investigating injury risk factors is needed in women's netball.
- Following a three-round Delphi approach, experts reached consensus on 61 risk factors for injury in netball.
- Risk factors were grouped into 'individual characteristics', 'lifestyle', 'training and competition', 'sport science and medicine provision' and 'facilities and equipment' highlighting the range of risk factors and complexity of injury mitigation in women's netball.
- Most risk factors were deemed a 'high' priority; however, seven risk factors were deemed 'very high' or 'high-very high': poor landing technique/mechanics', 'poor deceleration control/mechanics', 'insufficient rest and recovery', 'inadequate preparation for the

intensity of competition', 'previous injury', 'players continuing to play or train whilst injured (i.e., not reporting and injury), and 'poor/ lack of return to play protocols'.

- The risk factors deemed the highest priority for mitigation were across different groups ('individual characteristics', 'lifestyle', 'training and competition', 'sport science and medicine provision') indicating the need for a multi-disciplinary approach to the development of injury prevention strategies.

Introduction

Netball is one of the world's most popular women's sports, with >20 million participants[1] and a recent increase in popularity among men.[2] It is played across all ages, predominantly in Commonwealth countries, with professional or semi-professional women's competitions in Australia, New Zealand, the United Kingdom, and South Africa.[1] Netball is a dynamic, high-intensity, court-based sport with frequent accelerations, decelerations, direction changes, and jumps.[3,4] In recent years, there has been a growth in netball research, which has aligned with professionalisation and increased popularity of the sport.[5] Since the 1990s, injury has been the most researched topic in netball.[5] Injury rates have been investigated across a range of cohorts, including club,[6] national,[7] and international level,[8] with a recent systematic review reporting 11.3-14.0 injuries per 1000 hours in recreational netball and 19.4 injuries per 1000 player hours at the elite level.[9] The lower limb is reported as the most common injury site, with jump-landing, trips/slips/falls, and contact with another player or the ball, as the most common mechanism of injury. [5,8,9] In the 2019 Netball World Cup, 14 time-loss injuries were reported over a 10-day period, with 36% occurring at the ankle.[8] In a systematic review of ankle injuries in team sports, the highest incidence (45.6 per 1000 person-exposure) was reported in netball matches.[10]

Injury prevention is a focus within the sport and for netball governing bodies. Several netball-specific injury prevention programmes have been developed, including the NetballSmart (New Zealand)[11] and KNEE (Netballers and Enhance performance and Extend play', Australia).[12] Research has highlighted the success of these programmes in improving landing mechanics[13] and some physical performance measures (e.g., vertical jump height).[11] However, these programmes have an isolated focus on the injury mechanism (e.g., landing technique), not including other interacting risk factors and the 'complex system' approach to sports injuries[14]. The evidence of the wider implementation of these programmes is also limited,[15] with low implementation reported in community netball.[12] Additionally, their impact on injury outcomes is currently still unknown.

Supporting the implementation of injury prevention programmes and strategies requires a multi-disciplinary approach that considers all injury risk factors.[16] Several injury risk factors have been identified in netball, such as age[7], playing level[17] and physical performance measures (e.g., stiffness and balance).[18,19] Such research has been summarised until 2020 in a broad review on injuries in netball [9]. However, with the rapid increase in research in recent years,[5] a specific and updated systematic review of injury risk factors in netball is warranted. Additionally, current literature appears to focus predominantly on individual player characteristics as risk factors.[9] Further understanding of both modifiable and non-modifiable risk factors is needed to support the development of targeted injury prevention programmes. A recent study in women's rugby league identified other modifiable

areas of injury risk factors, such as: ‘Lifestyle and Environment’, ‘Training and Match’ factors and ‘A Lack of Provision’ factors, via a Delphi method consensus exercise with experts.[20] A Delphi method involving experts in netball may provide a robust process to achieving consensus on a set of multi-disciplinary injury risk factors and their importance.[21–23] Therefore, this two-part study aimed to first identify injury risk factors in netball within current literature via a systematic review (part-one); and second, establish consensus on injury risk factors, and their priority for mitigation, in netball utilising a Delphi method (part-two).

Methods

This study ensued in two parts; part-one: a systematic review, and part-two: a three-round Delphi consensus method. The findings from part-one (the systematic review) informed round one of the Delphi (part-two). Institutional ethics approval was obtained (ref: 115844) from Leeds Beckett University Research Ethics Committee.

Part 1: systematic review

The systematic review was carried out in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) protocol.[24] The protocol was registered with the PROSPERO international prospective register for systematic reviews (registration number: CRD42023438840) prior to the commencement of the review.

Search strategy

A systematic search of five electronic databases (PubMed, Scopus, MEDLINE, SPORTDiscus and CINAHL) was performed from the inception until 28th June 2023. Using previously published injury risk factor reviews[25,26]) as a guide, databases were searched using a combination of key words: netball AND (injur*) AND (risk OR risk factor* OR association OR caus*). Searches were performed in the title and abstract fields. Reference lists of selected studies were manually searched for additional eligible papers.

Study selection

After eliminating duplicates, search results were screened independently by two researchers (SW, LM) against the eligibility criteria. There was 95% agreement between reviewers during title and abstract screening, and 97% during full-text screening. Disagreements were resolved through discussion or via a third researcher (BJ). Articles that could not be eliminated by the title or abstract were retrieved and evaluated for inclusion via a full-text review. The title and authors were not masked to the reviewers.

Inclusion and exclusion criteria

Studies were eligible for inclusion if they investigated risk factors for injury netball across all playing levels and ages and any geographical location. Given the growth in participation and research in men's netball[2,27] studies investigating both men's and women's netball were eligible for inclusion. Only primary research investigations in peer-reviewed journals were included. All study types (e.g., retrospective, prospective, cross-sectional, cohort) were included. Studies were excluded if they did not aim to investigate risk factors for injury in netball or investigated mechanisms (i.e., the inciting event) of injury only. For example, Mullaly et al.[28] investigated the inciting event (mechanism) of knee injuries but did not investigate risk factors, and Sinclair et al.[29] report injury rates by position and time in game, but do not aim to investigate them as risk factors. Studies investigating netball injury prevention were included if they aimed to investigate risk factors. Studies that did not differentiate outcome measures between netball and other sports were excluded. Review articles, conference proceedings and other grey literature were excluded. Papers from all languages were included. When authors could not be contacted to retrieve full texts, studies were excluded.

Data extraction and synthesis

The following data were extracted from the included studies: study details (i.e., authors, publication details), study design (i.e., type of study, duration), sample (i.e., size, age grade, playing level, sex), independent (i.e., the risk factors) and dependent variables (i.e., injury assessment, location, type), probability and risk data (i.e., odds ratio, incidence rate ratios). Authors were contacted if data needed to be obtained or confirmed, when authors could not be contacted summary findings only were reported. WebPlotDigitizer (Version 4.8) was used to extract data from figures where required. All key findings relating to injury risk factors were extracted.

Risk of bias

Critical appraisal of individual articles was performed independently by two reviewers (SW, LM) using recommendations from the Grading of Recommendations Assessment Development and Evaluation (GRADE) working group[30], and following previous research[31] and recommendations[32] in sports medicine. The Downs and Black checklist[33] was used as the initial appraisal tool. Based on previous literature, the checklist was modified to fit the research question, with 14 remaining applicable items.[34] A score of '0' for "absent or insufficient information provided" or '1' for "item is explicitly described" was assigned to the criteria. Each study was assigned an a-priori quality rating based on the overall

score of the Downs and Black; “excellent” (13-14), “good” (10-12), “fair” (8-9) and “poor” (≤7).[34] This rating was then either maintained or downgraded based on two questions that were considered key to the grading of the study: 1) do the authors provide a clear definition for injury, including if 'medical attention' only, or 'time-loss'? and 2) do the authors provide an appropriate measure of risk within their analysis (e.g., risk ratio, odds ratio, logistic regression). For each question, the quality rating was maintained if the answer was yes; if the answer was no, the quality rating for study was downgraded one level.[31,32] If the answer was no for both questions, the study was downgraded two levels (i.e., one per each question) to the lowest quality rating of ‘very poor’. These specific questions were included due to limitations in injury studies reporting and using varying injury definitions[35] and their impact on the interpretation of the results,[36] as well as insufficient analysis in the methodological approach.[37] A final quality of evidence rating was provided, categorised as “excellent”, “good”, “fair”, “poor” or “very poor”. No studies were excluded based on quality. Any differences in ratings between reviewers were resolved through discussion or via a third researcher (BJ).

Best evidence synthesis

A best evidence synthesis was used to collate the evidence of risk factors due to the lack of methodological consistency which meant that a meta-analysis could not be conducted.[38,39] The level of evidence was determined in line with the guidelines[39] and previous literature [34,40]; *strong evidence:* provided by ≥ two studies with excellent or good quality with ≥75% of studies reporting consistent findings, *moderate evidence:* provided by one study with excellent or good quality, or ≥ two studies with fair or poor quality with ≥75% of studies reporting consistent findings, *limited evidence:* provided by only one study with fair or poor quality, *conflicting evidence:* inconsistent findings in multiple studies (<75% of studies reporting consistent findings).

Part 2: Delphi method

A three-round Delphi consensus method[23,41,42] was used to establish consensus on injury risk factors in netball and establish their priority for mitigation. The Delphi method was conducted between September and November 2023 using the online software Qualtrics (Qualtrics, Provo, USA), and is reported following the ACCORD (ACcurate Consensus Reporting Document) checklist.[43] No studies on men’s netball were identified in the review therefore the focus of the Delphi was on women’s netball.

Participants

A panel of 19 experts was established. To achieve reliable results, a Delphi panel should contain >10 experts.[44] To be included in the expert panel, participants were required to meet one or more of the following criteria: (a) currently a coach or performance support staff (medical and sport science) in high-performance (i.e., performance pathway, semi-professional, professional, international) netball, (b) published research regarding injury in netball, or (c) a minimum of 3 years' experience working with women athletes in a high performance setting. Forty-two experts were recruited using a purposive sampling technique based on the aforementioned criteria.[45]

The expert panel consisted of men (n = 6) and women (n = 13), from five different countries (United Kingdom n = 11, Australia n = 3, South Africa n = 2, New Zealand n = 2, Finland n = 1). The field of expertise of the panel included medical doctors (n = 2), physiotherapists (n = 5), strength and conditioning coaches (n = 5), netball coaches (n = 4) and researchers (n = 3), with 15.5 ± 8.6 (range: 4 to 30) years' experience. The level of experience for practitioners working in netball varied from international (n = 10), elite club (n = 3) and elite pathway (n = 2), with two practitioners working in working in international women's rugby union. The panel did not include any players, focusing on the experts and stakeholders who are the decision makers within the environments. The athletes' voice will be captured in follow up investigations. All participants gave informed consent prior to participating in the Delphi. For each round, participants had two weeks from the date of initial invitation to respond and complete the online form.

Round 1

The expert panel were asked to provide a list of items they believed to be risk factors for injury in netball. Following the completion of round one, the steering group (SW, LM, OH, LC) used qualitative analysis to refine the list of risk factors from the experts and identify groups of risk factors[46]. Risk factors were combined with those identified in the systematic review (part one) and duplicate risk factors were removed, resulting in 107 risk factors across five groups and 16 sub-groups (Supplementary Material 1A).

Round 2

Each of the 107 risk factors for injury were listed next to a five-point Likert scale (1 – *strongly disagree*, 2 – *disagree*, 3 – *neither agree nor disagree*, 4 – *agree*, 5 – *strongly agree*). Participants were asked to indicate their level of agreement on whether they perceived the risk factor would contribute to the risk of injury in netball. Consensus was reached for each factor if ≥80% agreement (with <10% disagreement) was achieved between the expert panel.[20,47] Participants were also asked to provide any comments on the identified risk

factors and propose any additional ones. Risk factors that did not reach consensus were amended based on the comments provided.

Round 3

A second round of agreement ratings were attained for risk factors that did not reach agreement in round one, including the additional proposed risk factors (n = 3). The risk factors were listed with the median (interquartile range [IQR]) level of agreement reached in round two, allowing experts to reflect on the initial rating. Following round three, the risk factors that did not achieve ≥ 80% agreement (with <10% in disagreement) were deemed to have not reached consensus. During round three, experts were also asked to rate the priority of mitigating each risk factor on a five-point Likert scale (1 – *very low*, 2 – *low*, 3 – *neither low nor high*, 4 – *high*, 5 – *very high*).

Equity, diversity and inclusion statement

In part one, all studies were included, with no exclusion criteria based on sex, gender, race, ethnicity and socio-economic level. In part two consideration was given to recruiting a diverse panel of experts (e.g. sex/gender, ethnic origin, geographic location) representing different expertise, countries and playing standards, but consideration was not able to be given to socio-economic status. The research team consists of four females and four males, across three countries (United Kingdom, Australia, South Africa) and different stages of academic careers (including young researchers and Professors).

Patient and Public Involvement

The public was involved in the study's recruitment; the experts recruited for part two could share the recruitment information with others who meet the criteria for the expert panel. There was no other patient or public involvement in the production of this research.

Results

Part 1: Systematic review

Identification and selection of studies

Through the original database search, 2 570 records were identified. Following the removal of duplicates and screening for eligibility, 17 studies remained.[6,7,18,19,48–60] Figure 1 provides a schematic representation of the decision process.

** Insert Figure 1 near here**

Study characteristics

The characteristics of the 17 studies included in the review are shown in Supplementary Material 2. The study design and duration varied across studies, with 12 prospective (71%) and 5 retrospective (29%) study designs, and study duration ranging from a four-day tournament to five-years (Supplementary Material 2). The most common level of competition investigated was amateur (n = 11, 65%).[6,7,18,48–51,53,57,58,60] Most studies investigated senior / open age players (n = 15, 82%)[6,18,19,48–59] but eight of these studies (47%)[6,49,50,52,53,55,58,59] stated the inclusion of youth cohorts (i.e., Under-19 age group or below). Two studies (12%) investigated youth cohorts only[7,60]. The average age of participants ranged from ~11 to 24 years, with seven studies not reporting average age.

A range of injury definitions and methods of diagnosis were used (Supplementary Material 2). A 'time-loss' injury definition was used in four studies,[18,19,56,60] whilst two[54,55] used a medical attention definition, and one study[7] used both. The majority (n = 10, 59%) of studies did not report,[49,51–53,58,59] or no clear statement was provided,[6,48,50,57] as to whether time-loss or medical attention injuries were investigated. In nine studies,[19,48,50,52,56–60] injuries were 'self-reported', two of which conducted verification or validation.[50,57] Seven (41%)[6,7,18,19,51,53,54] studies used a physiotherapist or medical personnel to diagnose injuries. The method of reporting injury incidence varied between studies (i.e., match-hours, training-hours, player-hours, count, percentage or not reported; Supplementary Material 2); for studies that reported relative to player-hours, the incidence ranged from 1.74 per 1000 player-hours (time-loss ankle injuries only[18]) to 500.7 per 1000 player-hours (all medical attention injuries[55]). A range of intrinsic (e.g., foot type, limb asymmetry, age, ethnicity) and extrinsic (e.g., playing surface, training load, bracing) risk factors were investigated (Supplementary Material 2).

Study quality

The scores and ratings for the assessment of study quality are shown in Supplementary Material 3. Four studies were rated as 'good',[18,19,54,60] three as 'fair',[7,50,58] two as 'poor'[51,53] and eight as 'very poor'.[6,48,49,52,55–57,59]. Five studies (29%) maintained their a-priori rating, whilst eleven (65%) studies were downgraded from question 1, and eight (47%) from question 2 (Supplementary Material 3).

Risk factors

Twenty-four risk factors (intrinsic n = 19, extrinsic n = 5) for injury in netball were identified in the studies included in the review. Best evidence synthesis found eight risk factors (balance, hypermobility, stiffness, fatigue, motivation, muscle soreness, sleep and stress) to have *moderate evidence*, six (body fat percentage, limb asymmetry, personality trait, somatotype, surface and use of warm-ups) to have *limited evidence,* and ten (age, playing

experience, previous injury, body weight, body mass index, foot type, lower body power, anaerobic fitness, training load and bracing) to have *conflicting evidence* (Supplementary Material 4).

Part 2: Delphi

During round one, the experts collectively listed 227 risk factors. Following qualitative analysis and removal of duplicates, 104 unique expert-identified risk factors remained. Twenty-two of the 24 risk factors identified in part-one (systematic review) were identified by the experts, resulting in a total of 106 risk factors. Upon the extraction process, five groupings with 16 sub-groupings were identified. Supplementary Material 1 shows the number of risk factors in each group throughout the Delphi process.

Following round two, which had a 100% response rate from the experts, 51 risk factors reached agreement, and three additional risk factors were proposed. The remaining 55 and three additional risk factors were re-rated in round three. Round 3 had an 84% response rate. Following round three, a further ten risk factors reached agreement, resulting in 61 risk factors reaching consensus: 22 ‘individual characteristics’, 11 ‘lifestyle’, 14 ‘training and competition’, 6 ‘sport science and medical provision’ and 8 ‘facilities and equipment’ (Figure 2). Only nine of the risk factors that reached agreement were from those identified in the systematic review (part one); fifteen risk factors from the systematic review did not reach consensus.

** Insert Figure 2 near here**

Tables 1-5 display the risk factors that reached agreement, their median (IQR) level of agreement and median (IQR) rating of priority for mitigation; one risk factor had a median rating of priority of ‘very high’, six had median ratings of ‘high-very high’, 51 ‘high’ and 8 ‘neither low nor high’. Figure 3 displays the proportion of responses for the top-rated risk factors (i.e., those with >90% ratings of ‘high’ and ‘very high’ priority ratings combined). Only two risk factors had a 100% response rate of combined ‘high and very high’ priority for mitigation: ‘players continuing to play or train whilst injured (i.e., not reporting an injury’ and ‘relative energy deficiency in sport (RED-s)’. The distribution of responses of the remaining risk factors are shown in Supplementary Material 5.

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Insert Figure 3 near here

Discussion

This two-part study aimed to identify injury risk factors in netball reported in the current literature and use expert opinions to establish consensus on injury risk factors in netball and their priority for mitigation. Within the systematic review, 17 studies met the inclusion criteria, and 24 risk factors for injury in netball were identified. Following the Delphi method, 61 risk factors for injury in netball reached consensus (≥ 80% agreement and <10% disagreement), only nine of which were identified in the systematic review. The risk factors were categorised into five groups: 'individual characteristics' (n = 22), 'lifestyle' (n = 11), 'training and competition' (n = 14), 'sport science and medical provision' (n = 6) and 'facilities and equipment' (n = 8). Based on median ratings, most risk factors (n = 46, 75%) were deemed to a 'high' priority, but seven (12%) were deemed 'high-very high' or 'very high', including 'poor landing technique/mechanics', 'insufficient rest and recovery', and 'inadequate preparation for the intensity of competition'. This study identifies a range of risk factors for injury in netball, identifying focus areas of injury prevention and highlighting the importance of a multi-disciplinary approach to injury mitigation.

The 17 studies included in the systematic review identified 19 intrinsic and 5 extrinsic risk factors for injury in netball. Best evidence synthesis identified eight risk factors with *moderate* evidence (i.e., one study with good quality identified the risk factor, or more), six with *limiting* evidence (i.e., one study with fair or poor quality identified the risk factor) and ten with *conflicting* evidence (i.e., inconsistent findings in multiple studies). The low number of risk factors with *moderate* evidence and none with *strong* evidence is due to insufficient research on the risk factors and the study quality. Only four studies had final study quality ratings of 'good', with eight studies rated as 'very poor'. This is in line with a previous systematic review on injuries in netball, where only 18% of studies reported reliable and valid measures of injury exposure, and only 9% of studies were reported to have sufficient statistical analysis.[9] The high number of studies with *conflicting* evidence could be due to the different cohorts investigated or the varied data collection methods. These findings demonstrate that whilst injury is the most common area of research in netball,[5] studies directly investigating injury risk factors are limited and generally of poor quality. Therefore, further research of risk factors with larger prospective studies, clear and appropriate injury definitions and diagnostic approaches, and appropriate statistical analysis are required.

The limited current research is underscored by an additional 82 risk factors identified by experts in round one of the Delphi. Furthermore, the current literature focuses predominantly on individual characteristics, whilst the experts identified several risk factors relating to 'lifestyle' (i.e., nutritional practices, recovery, travel), 'training and competition' (i.e.,

nature of the sport, competition structure, physical preparation), ‘sport science and medical provision’ (i.e., medical and sport science support) and ‘facilities and equipment’ (i.e., footwear, netball court) that still need investigation. Of the 61 risk factors that reached consensus, only nine were identified in the systematic review in part one (balance, fatigue, sleep, limb asymmetry, surface, playing experience, previous injury, training load and use of warm-ups), five of which were deemed to have *moderate* evidence. Of the 15 risk factors identified in the systematic review that did not reach consensus, ten had *limited* or *conflicting* evidence associated. Body mass, body mass index and body fat percentage were all risk factors identified in the review, with *conflicting* evidence, that did not reach consensus. However, body mass and body mass index have been reported to be a risk factor for lower limb injury in a meta-analysis on female team sport athletes, with greater body mass identified as a risk factor for anterior cruciate ligament (ACL) injury risk specifically.[40] Additionally, in women's rugby league, experts have identified high body fat percentage as a risk factor for injury.[20] Whilst these risk factors, and others, did not reach consensus by experts in the current study, they could be considered for future injury risk research to build on the existing evidence base, specifically in netball. However, based on the findings of the Delphi they should not be a focus for developing netball-specific mitigation strategies at this stage.

The 61 risk factors for injury in netball agreed by the experts covered five areas: ‘individual characteristics’, ‘lifestyle’, ‘training and competition’, ‘sport science and medical provision’ and ‘facilities and equipment’ (Tables 1-5). Some of these risk factors are specific to netball, such as those in the ‘nature of the sport/rules’ group and ‘netball court’ subgroupings. Others align with the broader injury risk literature, but the mitigation should be considered in netball-specific contexts. For example, the injury risk factors relating to ‘training load and recovery’ have been investigated and considered in multiple sports,[61,62] but the netball training environments should be considered. In netball talent development systems, players often train and compete for multiple teams and as a result, likely undergo early specialisation.[63] Experts in the present study have identified ‘competing for multiple teams’ as a risk factor for injury. Therefore, several risk factors could be mitigated by considering the netball-specific talent pathway structures and putting specific mitigation strategies in place. The lack of ‘sport science and medicine provision’ risk factors that reached consensus are similar to the ‘lack of provision’ risk factors identified in women’s rugby league.[20] Similarly, gendered-environment risk factors have been previously proposed when considering the ACL specifically,[64] with risk factors discussed by Parsons et al.[58] similar to those identified by experts in the current study for netball specifically (e.g., ‘negative belief / attitude toward strength training [i.e., negative association with strength training and body image]’). The broad range of risk factors for injury in netball, as agreed by the experts, highlights the need for a multi-disciplinary approach to injury mitigation.

The risk factors that reached consensus were rated on their priority for mitigation. ‘Poor landing technique/ mechanics’ was the only risk factor with a median rating of ‘very high’ (median [IQR] = 5 [1]), followed by six risk factors with a median rating of ‘high-very high’: ‘poor deceleration control / mechanics’ (4.5 [1]), ‘previous injury’ (4.5 [1]), ‘insufficient rest and recovery’ (4.5 [1]), ‘players continuing to play or train whilst injured’ (i.e., not reporting an injury) (4.5 [1]), ‘inadequate preparation for the intensity of competition’ (4.5 [1]) and ‘poor / lack of return to play protocols’ (4.5 [1]) (Table 4). All other physical quality risk factor ratings, except ‘low aerobic fitness’ had median ratings of ‘high’ priority for mitigation. The priority of the physical quality risk factors is in line with current injury prevention programmes, such as the NetballSmart (New Zealand)[11] and KNEE programme (Australia).[12] These programmes have been found to improve the physical quality risk factors that reached consensus: landing mechanics,[13] balance [65] and trunk strength.[11] However, there is currently limited evidence of their implementation in real-world settings and their efficacy for reducing injuries.[12,66] In community settings, low implementation of the KNEE programme is reported,[12,66] and only 59% of those who adopt it, use all categories, with the balance / landing and agility components having the lowest use[66]. Additionally, provision of feedback on technique for deceleration among adopters was only 54%,[66] indicating the need for focused implementation science approaches to support adoption of injury prevention strategies.[67] The priority ratings of the physical quality risk factors identified in the current study highlight the need for continued effort to implement such injury prevention programmes, with further research needed to investigate their adoption, including barriers and facilitators to implementation.

Eight of the eleven top rated risk factors were from ‘training and competition’, ‘lifestyle’ and ‘medical and sport science provision’ categories (Figure 3), highlighting the limitation of injury prevention strategies that focus solely on individual player characteristics, particularly physical qualities. This is in line with the complex systems approach to sports injuries proposed by Bittencourt et al.[14] where risk factors form a ‘web of determinants’ that interact together to create a risk profile. For example, the ‘poor balance and proprioception’ is influenced by, and influences, other risk factors such as ‘landing technique / mechanics’, ‘insufficient rest and recovery’ and ‘low energy availability’. It is seldom that only one risk factor is responsible for injury[14], therefore injury prevention strategies should not focus on improving one risk factor alone (e.g., balance) but should consider its complex interaction with the other risk factors and consider a holistic approach (e.g., reduce fatigue, improve recovery and nutritional strategies). The ‘medical and sport science provision’ risk factors that reached consensus and were rated a high priority (Figure 3 and Table 4), further supports the need for a multi-disciplinary approach to injury prevention in netball.

The risk factors with higher ratings of priority provide some guidance for the focus of mitigation strategies. However, it should be acknowledged that these are not environment-specific ratings, and the priority of the risk factors may differ for different environments. For example, in elite environments, risk factors in the category 'facilities and equipment' would likely be deemed a lower priority than in community environments due to the minimum requirements put in place at the elite level. Furthermore, the feasibility of mitigating the risk factors in specific environments should also be understood before developing and implementing mitigation strategies. Risk factors could be deemed a priority but have low feasibility to mitigate and, may not be the best focus for mitigation strategies.[20] For example, the sport science and medicine support may be deemed a high priority but the feasibility of mitigation at the community level will be low due to limited financial resources.

Clinical and research implications

This study has identified risk factors for injury in women's netball, which should be considered clinically in injury risk mitigation and prevention strategies. The range of risk factors that reached consensus by the experts further highlights the complexity of sports injuries[14] and the need for a multi-disciplinary approach to reduce the risk of injury in netball in practical environments. The risk factors deemed a high priority should be considered by governing bodies, clinicians, and sport science practitioners as focus areas for mitigating injury in women's netball. For example, governing bodies could consider the structure and implementation of talent development programmes to mitigate several identified risk factors (e.g., competing for multiple environments and lack of medical provision). Clinicians and practitioners should focus on high priority individual characteristic risk factors, such as landing technique, whilst also considering the external risk factors that could be mitigated in their environment, such as lifestyle factors (e.g., recovery). The risk factors identified can guide future high-quality research on injury risk in netball to further support the development of appropriate injury prevention programmes, such as specific investigation into the feasibility of implementing specific strategies to improve efficacy.

Strengths and Limitations

This is the first study to systematically review injury risk factor research in netball. The inclusion and exclusion criteria were specific to include studies that aimed to investigate injury risk factors only; whilst this ensured specificity in the studies included, it could have limited the sample and would explain the difference in the number of studies identified to previous reviews.[9] The identified risk factors for injury were extracted and summarised through best evidence synthesis only (i.e., no meta-analysis) due to the heterogeneity of the methodologies, definitions and statistical analysis limiting the ability to conduct further synthesis. Future

research should consider the definitions, diagnosis, and methodological approaches to improve the quality of the research and support the synthesis of findings. Additionally, the literature search for the systematic review was only conducted until June 2023. Given the rapid progression of research in netball,[5] further research investigating the risk factors of injury in netball may have been published following the completion of the systematic review component. However, given the findings of the review informed the Delphi method consensus exercise, the review was not updated.

A Delphi approach with experts to establish consensus on injury risk factors in netball was conducted to support the limited literature. Whilst recruitment of the expert panel was considered to ensure representation from men and women, different ethnic origins, expertise, countries and playing standards, the final expert panel had a high percentage of experts from well-developed countries and experience working at the elite and international level. This may have introduced bias into the ratings, particularly the priority for mitigation of risk factors, which could reduce the generalisability of the findings across all levels of competition, particularly the youth and community environments.

We acknowledge that players' views and expertise are important. They are (or should be) central to clinical and injury risk mitigation decision-making. Excluding players from the Delphi panel is therefore an important limitation of this study. We lost the player's voice, and likely key perspectives, in the consensus process; their unique insights and perspectives would have enriched this consensus exercise. Importantly, players should be key partners in decision making within their sport. Follow up investigations, including into the barriers and facilitators to injury risk factors, will include players to capture the athletes' voice to support, for example, the development and implementation of injury mitigation strategies.

Conclusion

Combining a systematic review and Delphi method, this study reports a Delphi method consensus exercise on injury risk factors in netball and priority ratings for risk factor mitigation. Experts reached consensus on 61 injury risk factors in netball across five risk factor groups: individual characteristics, lifestyle, training and competition, sport science and medical provision, and facilities and equipment. The findings highlight the complexity of injury risk in netball, and the need for multi-disciplinary injury prevention research and clinical practice. Extrinsic risk factors are particularly important. Expert priority ratings spotlighted specific areas for research on mitigation strategies in netball but further research on the priority and feasibility in specific environments (i.e., elite, sub-elite and community) is required.

Contributors

SW, DCJvR and BJ conceptualised the research project and designed the study. SW and LM completed the systematic review screening and data extraction and synthesis. SW led data collection of the Delphi and SW, LM, OH, LC and DCJvR conducted the analysis of the three rounds. SW and AF developed the figures and tables in the manuscript. SW wrote the first draft of the manuscript. All authors contributed to the subsequent drafts and approved the final manuscript. SW is the guarantor.

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Competing interests

SW receives funding from Leeds Rhinos Netball. LM is part-funded by England Netball. DCJvR is affiliated to World Netball.

Ethical approval

This study involves human participants. The study received ethical approval from Leeds Beckett University (ref. 115844). Participants gave informed consent to participate in the study prior to taking part.

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Table 1. The rating of agreement (median [interquartile range]) and priority, of the 22 'individual physical characteristics' risk factors that reached consensus.

Individual Physical Characteristics Risk factors	Modifiable or non-modifiable	Agreement		Priority
		Round	Median (IQR)	Median (IQR)
Individual player characteristics (n = 2)				
Young training age (i.e., players with lower playing experience) increases the risk of injury	Non-modifiable	1	4 (0)	4 (1)
Low bone mineral density (bone health) increases the risk of injury	Modifiable	1	5 (1)	4 (1)
Physical qualities (n = 14)				
Poor balance and proprioception increase the risk of injury	Modifiable	1	5 (1)	4 (0.5)
Low aerobic fitness increases the risk of injury	Modifiable	1	4 (0)	3 (1.25)
Low core / trunk strength increases the risk of injury	Modifiable	1	4 (0)	4 (0)
Low hip strength increases the risk of injury	Modifiable	1	4 (0)	4 (0)
Low thigh strength increases the risk of injury	Modifiable	1	4 (0)	4 (0)
Low calf strength increases the risk of injury	Modifiable	1	4 (0)	4 (0.25)
Poor quadricep to hamstring strength ratio increases the risk of injury	Modifiable	1	4 (0)	4 (1)
Limb asymmetry (>10%) - hop performance increases the risk of injury	Modifiable	1	4 (0)	4 (1)
Poor landing technique / mechanics increases the risk of injury	Modifiable	1	5 (0.5)	5 (1)
Poor deceleration control / mechanics increases the risk of injury	Modifiable	1	5 (0.5)	4.5 (1)
Changes in movement characteristics and strength through peak height velocity (i.e., maturation) increase the risk of injury	Modifiable	1	4 (0)	4 (0.25)
Ankle instability increases the risk of injury	Modifiable	1	5 (1)	4 (1)
Poor mobility increases the risk of injury	Modifiable	2	4 (0)	4 (1.25)
Limb asymmetry (>10%) - agility performance increases the risk of injury	Modifiable	2	4 (0)	4 (0)
Medical (n = 4)				
Previous injury increases the risk of injury	Non-modifiable	1	5 (1)	4.5 (1)
Illness increases the risk of injury	Modifiable	1	4 (0)	3.5 (1.25)
Chronic medical conditions increase the risk of injury	Non-modifiable	1	4 (0)	4 (1.25)
Relative energy deficiency in sport (RED-s) increases the risk of injury	Modifiable	1	5 (1)	4 (1)
Psychological characteristics (n = 2)				
Negative belief/ attitude toward strength training (i.e., negative association with strength training and body image) increases the risk of injury	Modifiable	1	4 (0)	4 (1)

Low cognitive ability (i.e., inability to read game situations to avoid hazardous situations) increases the risk of injury	Modifiable	2	4 (0.5)	3.5 (1)

Agreement rating: *1 - strongly disagree, 2 – disagree, 3 – neither agree nor disagree, 4 – agree, 5 – strongly agree*
Priority rating*: 1 – very low, 2 – low, 3 – neither low nor high, 4 – high, 5 – very high*

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Table 2. The rating of agreement (median [interquartile range]) and priority, of the 11 ‘lifestyle’ risk factors that reached consensus.

Lifestyle Risk factors	Modifiable or non-modifiable	Agreement	Priority	
		Round	Median (IQR)	Median (IQR)
Nutritional practices (n = 4)				
Poor or inadequate hydration increases the risk of injury	Modifiable	1	4 (0)	3 (1)
Poor or inadequate nutrition increases the risk of injury	Modifiable	1	5 (1)	4 (0)
Low energy availability increases the risk of injury	Modifiable	1	5 (1)	4 (0.25)
Iron deficiency increases the risk of injury	Modifiable	2	4 (0)	4 (1)
Recovery (n = 6)				
Insufficient rest and recovery increase the risk of injury	Modifiable	1	5 (1)	4.5 (1)
Early or late training times that impact recovery (e.g., sleep) increase the risk of injury	Modifiable	1	4 (0)	4 (1)
Tiredness due to non-related netball activities (i.e., work or lifestyle) increases the risk of injury	Modifiable	1	4 (0)	4 (1)
Poor sleep duration increases the risk of injury	Modifiable	1	4 (0)	4 (0)
Poor sleep quality increases the risk of injury	Modifiable	1	4 (0)	4 (0)
High fatigue in the lead up to training / competition increases the risk of injury	Modifiable	1	5 (1)	4 (1)
Travel (n = 1)				
Travel across multiple (>5) time zones increases the risk of injury	Non-modifiable	1	4 (0)	3.5 (1)

Agreement rating: *1 - strongly disagree, 2 – disagree, 3 – neither agree nor disagree, 4 – agree, 5 – strongly agree*
Priority rating*: 1 – very low, 2 – low, 3 – neither low nor high, 4 – high, 5 – very high*

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Table 3. The rating of agreement (median [interquartile range]) and priority, of the 14 'training and competition' risk factors that reached consensus.

Training and Competition Risk factors	Modifiable or non-modifiable	Agreement	Priority	
		Round	Median (IQR)	Median (IQR)
Nature of the sport/ rules (n = 2)				
Contesting for the ball (resulting in contact) increases the risk of injury	Modifiable	1	4 (0)	3 (1)
Confined spaces of the court (i.e., positional restrictions on court, resulting in hard decelerations) increase the risk of injury	Modifiable	2	4 (0.5)	3 (1.25)
Competition structure (n = 3)				
Congested fixtures (i.e., close consecutive games with minimal recovery) increase the risk of injury	Modifiable	1	4 (0)	4 (0.5)
Players are at increased risk of injury early in the season (e.g., if pre-season training does not provide appropriate preparation)	Modifiable	2	4 (0)	4 (0.25)
A long off season increases the risk of injury (e.g., if sufficient maintenance work is not carried out)	Modifiable	2	4 (0)	4 (1)
Physical preparation (n = 4)				
Poor warm-ups (due to lack of time or inappropriate exercises) increase the risk of injury	Modifiable	1	4.5 (0.5)	4 (0)
Players continuing to play or train whilst injured (i.e., not reporting an injury) increases the risk of injury	Modifiable	1	5 (0)	4.5 (1)
Inadequate preparation for the intensity of competition increases the risk of injury	Modifiable	1	5 (0)	4.5 (1)
Insufficient plyometric exposure increases the risk of injury	Modifiable	1	4.5 (0.5)	4 (1)
Training load and recovery (n = 5)				
Overtraining increases the risk of injury	Modifiable	1	5 (1)	4 (1)
A spike (i.e., sudden increase) in training load increases the risk of injury	Modifiable	1	5 (0)	4 (1)
Large fluctuations in training load increase the risk of injury	Modifiable	1	4 (0)	4 (0)
Competing for multiple teams increases the risk of injury	Modifiable	1	4 (0)	4 (1.25)
Lack of rest between tournaments increases the risk of injury	Modifiable	1	5 (1)	4 (1)

Agreement rating: *1 - strongly disagree, 2 – disagree, 3 – neither agree nor disagree, 4 – agree, 5 – strongly agree*
Priority rating*: 1 – very low, 2 – low, 3 – neither low nor high, 4 – high, 5 – very high*

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Table 4. The rating of agreement (median [interquartile range]) and priority, of the six 'sport science and medical provision' risk factors that reached consensus.

Sport Science and Medical Provision Risk factors	Modifiable or non-modifiable	Agreement	Priority	
		Round	Median (IQR)	Median (IQR)
Medical support (n = 2)				
Poor / lack of return to play protocols increases the risk of injury	Modifiable	1	5 (1)	4.5 (1)
Lack of, or insufficient, physiotherapy support increases the risk of injury	Modifiable	1	4.5 (0.5)	4 (1.25)
Sport science support (n = 4)				
Lack of, or insufficient, strength and conditioning support increases the risk of injury	Modifiable	1	5 (1)	4 (1)
Lack of, or insufficient, nutrition support increases the risk of injury	Modifiable	1	4.5 (0.5)	4 (2)
Lack of, or insufficient, sport science support increases the risk of injury	Modifiable	2	4 (1)	4 (0.25)
Lack of sport science and medicine education (e.g., injury management, load management, nutrition)	Modifiable	2	4 (1)	4 (1)

Agreement rating: *1 - strongly disagree, 2 – disagree, 3 – neither agree nor disagree, 4 – agree, 5 – strongly agree*
Priority rating*: 1 – very low, 2 – low, 3 – neither low nor high, 4 – high, 5 – very high*

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Table 5. The rating of agreement (median [interquartile range]) and priority, of the eight 'facilities and equipment' risk factors that reached consensus.

Facilities and Equipment Risk factors	Modifiable or non-modifiable	Agreement	Priority	
		Round	Median (IQR)	Median (IQR)
Footwear (n = 2)				
Lack of appropriate footwear increases the risk of injury	Modifiable	1	5 (1)	4 (1)
Ill-fitting footwear increases the risk of injury	Modifiable	1	4 (0)	4 (0)
Netball court (n = 6)				
A slippery court surface increases the risk of injury	Modifiable	1	5 (1)	4 (2)
Foreign objects on the court surface increase the risk of injury	Modifiable	1	5 (1)	4 (1.25)
Freestanding netball posts (i.e., bases non-sunken) increase the risk of injury	Modifiable	1	4 (1)	3 (1)
Wet court surfaces due to the weather on outdoor courts increase the risk of injury	Modifiable	1	4.5 (0.5)	4 (2)
A concrete court surface increases the risk of injury	Modifiable	1	4 (0)	3 (1)
Playing or training on a surface type not accustomed to increases the risk of injury	Modifiable	2	4 (0.5)	4 (2)

Agreement rating: *1 - strongly disagree, 2 – disagree, 3 – neither agree nor disagree, 4 – agree, 5 – strongly agree*
Priority rating*: 1 – very low, 2 – low, 3 – neither low nor high, 4 – high, 5 – very high*
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