Title:
Situations and mechanisms of non-contact knee injury in adult netball: A systematic review

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ABSTRACT

Objectives

Noncontact knee injuries in netball are a concern due to a range of negative consequences. To reduce the number of injuries, identifying the situation and mechanism of injury is important. This systematic review examined the literature reporting the situation and mechanism of noncontact knee injury in netball.

Design

Systematic Review.

Methods

PRISMA guidelines were followed and specific key-term combinations used to search databases. Descriptive and analytic-observational studies reporting the situation or mechanism of noncontact knee injury in females playing netball were included (evaluated using frequency counts).

Results

Six articles were included (combined sample 11401). Players self-reported the situation of injury in five studies, only one study reported both the situation and mechanism of injury. Landing was the most reported situation of knee injury, representing 46.6% of all knee injuries whilst knee abduction (valgus) collapse was the most observed mechanism. Situation and mechanism of noncontact knee injury in netball were not adequately reported.

Conclusions

Despite the variations in reporting methods, landing is the most common situation of injury. As only one study reported mechanism of injury, it is difficult to draw conclusions

but the mechanism of noncontact knee injury in netball appears similar to those identified in other female athletes.

Keywords

- Knee
- Landing
- Abduction
- ACL

Highlights

- Knee injuries accounted for 15.1% of all injuries in netball
- The most common situation of injury was landing occurring in 46.6% of knee injuries
- Most landings (53.9%) were single-leg landings
- Knee abduction (valgus) collapse was evident in 75% of knee injuries
- In 68.8% of knee injuries, trunk position was an important consideration

INTRODUCTION

Netball is a fast-paced, explosive sport requiring quick changes of direction and multiple jumps, leaps, and sprints.[1] Netball is primarily played in Commonwealth countries,[2] predominantly by females,[2] with a worldwide participation of 20 million players.[2] In 2015, there were 104,000 players regularly participating in netball in England.[3] Following England's Commonwealth Games netball gold medal in 2018, there was an additional uptake of 130,700 women playing netball.[4] Since the Netball World Cup was hosted in Liverpool in July 2019, England Netball has reported further increases in participation to 319,400 adults.[4] Netball is also growing in popularity across the world and is now played in 113 countries worldwide. [2] The advent of professional leagues in Australia [5] and New Zealand,[6] and the introduction of full-time contracts for players selected by England Netball,[7] reflects the growing investment and interest in the sport. With increased sport participation comes increased injury frequency,[8] and female athletes with moderate to high competition volumes have been reported specifically as being at increased risk of lower-limb injury. [9]

Studies investigating injuries in netball date back to the 1980s.[10-15] Authors have consistently found that the ankle is the most common injury site with a reported frequency of 29-84% of all netball injuries [10-15] followed by the knee with a reported frequency of 8.3-42% of all netball injuries.[10-15] Knee injuries, however, tend to be more severe, defined by the greatest amount of time out of sport[16] and the frequent need for surgical intervention.[16] Of particular concern are anterior cruciate ligament (ACL) injuries[17] due to high short-term treatment costs (e.g. surgery)[17] and the high proportion of individuals who are unable to return to pre-injury levels of performance.[18] Such injuries are also of concern because it is estimated that between 50% and 100% of women with an ACL injury will show significant pain, functional limitations, and radiographic signs of knee osteoarthritis within 12 to 20 years of the original injury.[19]

Despite the recent evolution of professionalism in netball, injury frequency has remained relatively constant since the 1980s.[10-15] The anatomical location of injuries sustained are comparable at both elite and recreational levels, but the incidence rate may be higher in elite level players.[20]

According to van Mechelen et al.,[21] establishing the extent of an injury problem is the first step in reducing the risk of injury in a particular sport. The second step in the process is to ascertain factors involved in and mechanisms of injury in order for effective injury prevention interventions to be developed.[21,22] In the basketball,[23,24] handball,[24] and netball literature,[25,26] "factors" have been viewed specifically as including the 'situation' and 'mechanism' of injury. The 'situation' of injury refers to the specific context during which the injury occurred (e.g. when the injury occurred, where on the court the injury occurred, what the player was doing (landing, sudden-stop, passing, shooting)).[23-26] The 'mechanism' (mechanics) of injury refers to a biomechanical description of how the injury occurred (e.g. contact/noncontact, whole-body kinematic pattern, local joint kinematic pattern).[23-27] Given that the specific characteristics of a sport's situation will influence whole-body and local joint kinematic patterns,[28] and the same mechanics of injury (e.g. knee abduction (valgus) collapse) are indeed evident in different injury situations (e.g. attacking, defending, passing, shooting, landing, cutting),[23,24,26] detailed descriptions of both the situations and mechanisms (mechanics) of injury are needed to better understand the most frequent inciting events for knee injury in netball.[25,26]

Epidemiological studies in netball have documented the situation and mechanism of injury using a variety of methodologies.[10-12,14] It should be noted that although authors have used the term "mechanism of injury" studies have commonly reported the situation of injury under this umbrella term.[11,12,29,30] Some authors have used a retrospective self-reporting system where monthly telephone interviews were

conducted with players who recalled any injuries that had occurred in the previous month.[10,14] Other authors have used prospective designs recording injuries as they were sustained.[11,12] The available studies documented a range of different injury sites and injury types rather than focusing specifically on knee soft tissue injuries (e.g. ACL injury).[10-12,14] A more recent example using a systematic video analysis of ACL injuries in elite netball[26] provided detailed analysis of the situation and mechanism of 16 ACL injuries; it identified whether the injuries were noncontact, indirect contact, or contact in nature. The authors defined noncontact as an injury that occurred without any contact from another player, indirect contact as when there was contact between an opponent and the subsequently injured player on a part of the body other than the injured leg, and direct contact as when there was a direct blow to the injured knee.[26] Within their video analysis no direct contact ACL injuries were recorded.[26] Eight of the injuries sustained were noncontact in nature, and eight were indirect contact in nature.[26] Stuelcken et al.[26] provided detail about both the situation and mechanism of each of the injuries sustained in the video analysis to a much greater extent than other studies. The situations were clearly outlined as the game situation (e.g. stage of the game, part of the court); and the player's behaviour (e.g. player movement before injury, type of landing). The mechanism of injury provided detail about the local joint kinematic pattern when injury occurred (e.g. knee close to full extension, apparent knee abduction (valgus) collapse (i.e. knee collapses medially with simultaneous hip adduction, knee abduction, knee external rotation)).[23] These operational definitions of situation and mechanism of injury in netball are also consistent with those used by other authors.[25]

Although Stuelcken et al.[26] suggested that noncontact knee injuries and indirect contact knee injuries occur in similar proportions during netball, other evidence suggests that noncontact knee injuries are more common.[12,29,31] The reasons for this discrepancy may be due to the fact that other evidence has asked players to self-report their

injury.[12,29,31] Players may not accurately recall how their injury occurred. To reduce the risk of noncontact knee injury in netball, it is essential that there is an understanding of the situation and mechanism of netball noncontact knee injuries in order to develop preventative interventions. Attempts have been made to outline the situation of noncontact knee injury in netball but there is no clear consensus due to inconsistent methodologies.[10,12,14,15,29,30] The purpose of this systematic review was therefore to identify the situations and mechanisms of noncontact knee injury in adult netball players. Noncontact knee injury was defined as knee injury when there has been no contact with any part of the body.[32] Based on research to date,[12,15,26] it was hypothesised that the most common situation of injury would be landing while catching or contesting a ball. It was also hypothesised that the most common mechanism of injury would be knee abduction motion as observed in female athletes participating in other invasion games.[33] This review advances previous work in that it will specifically focus on the situation and mechanism of noncontact knee injury in netball. The anticipated significance of this review is that it will yield important information relevant to the second stage of the sequence of injury prevention[21,34] in a way that informs the design of future interventions intended to reduce the risk of noncontact knee injury in netball players.

MATERIALS AND METHODS

This review was registered on the International Prospective Register of Systematic Reviews (PROSPERO: ID = CRD42019135831) (PROSPERO), and followed all relevant items in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [35,36].

Search Strategy

Comprehensive electronic searches were performed on 4th June 2020 using one medical database (PubMed), one allied health database (PEDro), and one sports database (SportDiscus) using specific combinations of pre-defined key terms (Table 1). No Medical Subject Heading (MeSH) terms were used because research studies are listed in PubMed long before being indexed with MeSH terms; this means that placing emphasis on the use of MeSH terms can result in the most recently listed research studies not being captured.[37] Piloting of specific combinations of pre-defined key terms and study selection processes was performed and found to be effective.

Articles published from the inception of the databases were included. This approach was used following the prior pilot searches. The pilot searches produced a limited timeframe of studies on netball; therefore, it was deemed reasonable to keep this timeframe open.

Following database searches, duplicates were removed prior to two of the research team independently screening abstracts to ascertain eligibility for inclusion in the review. Following abstract screening, only full-text English language studies were obtained for further assessment of eligibility through a full-text review. Reference lists of studies were screened for studies that may have eluded the original search process.

Inclusion Criteria

This review only considered studies that recorded the situation and mechanism of first-time noncontact knee injury in netball involving female adults (age ≥18 years) and that were of descriptive (cross-sectional), and analytic-observational (cohort, cross-sectional, case-control) design. Included studies employed different methods of recording the situation and mechanism of noncontact knee injury including retrospective self-reported injury questionnaires, prospective recording of injury by a qualified healthcare practitioner, clinical review of hospital data, and a systematic video

analysis. Studies were excluded from this review if participants were male, aged less than 18 years, if the situation or mechanism of the noncontact knee injuries was not reported, if the injury was sustained when not playing netball, or if it was stated that the injury was a re-injury.

Data extraction and synthesis

Following eligibility assessment, data were extracted and entered into a customised Microsoft Excel spreadsheet (Appendix). Data included study characteristics (e.g. study design), study setting (training, match (league, tournament)), level of participation (e.g. recreational, elite, professional), study size (n), injured player's team position (e.g. Centre (C), Goal Defence (GD), Goal Attack (GA), Goal Keeper, Goal Shooter (GS), Wing Defence (WD), Wing Attack (WA)), participant characteristics (age, height, mass), situation of injury (e.g. landing following a jump to catch the ball), mechanism of injury (e.g. abduction collapse, knee hyperextension), and injury diagnosis (if any). Situations and mechanisms of injury are listed in Table 2. The presence or absence of a situation or mechanism of injury was coded as binary data (1=present; 0=absent). The two primary reviewers met to discuss the data extracted from the articles included in the full-text review and agreed on all data extracted. This review did not focus on any type of intervention. Therefore, as in other systematic reviews,[38] risk of bias within studies was not relevant to the purpose of this review and a quality assessment of included studies was also not performed.

Data analysis

Frequency counts of situations and mechanisms of noncontact knee injury were completed across the included studies (Appendix). Prevalence (%) of each situation was then calculated: (number of occurrences of specific situation ÷ total number of

situations) x 100. Prevalence (%) of each mechanism was then calculated also:

(number of occurrences of specific mechanism ÷ total number of mechanisms) x 100.

Item 1	Item 2
Netball	Noncontact
	Non-contact
	Knee
	Injury
	Trauma
	Adult
	Female
	Situation
	Mechanism
	Epidemiology
	Aetiology
	Etiology

Table 1. Pre-defined Key Terms and Key Term Combinations for Literature searches

Situations	Mechanisms
Landing	Apparent knee abduction collapse
Running – sudden stop (braking)	Knee at, or close to, full extension
Running – cutting	Hip internal rotation (on injured side)
Slipping/tripping	Trunk rotation relative to injured side
Treading on foot	Trunk lateral flexion relative to injured side
Rebounding	
Player contact	
Other	

Table 2. Situations and Mechanisms of Noncontact Knee Injury in netball

RESULTS

Search results and study identification process are illustrated in Figure 1. Full details and characteristics of the six studies included for the final data synthesis are presented in the Table 3.

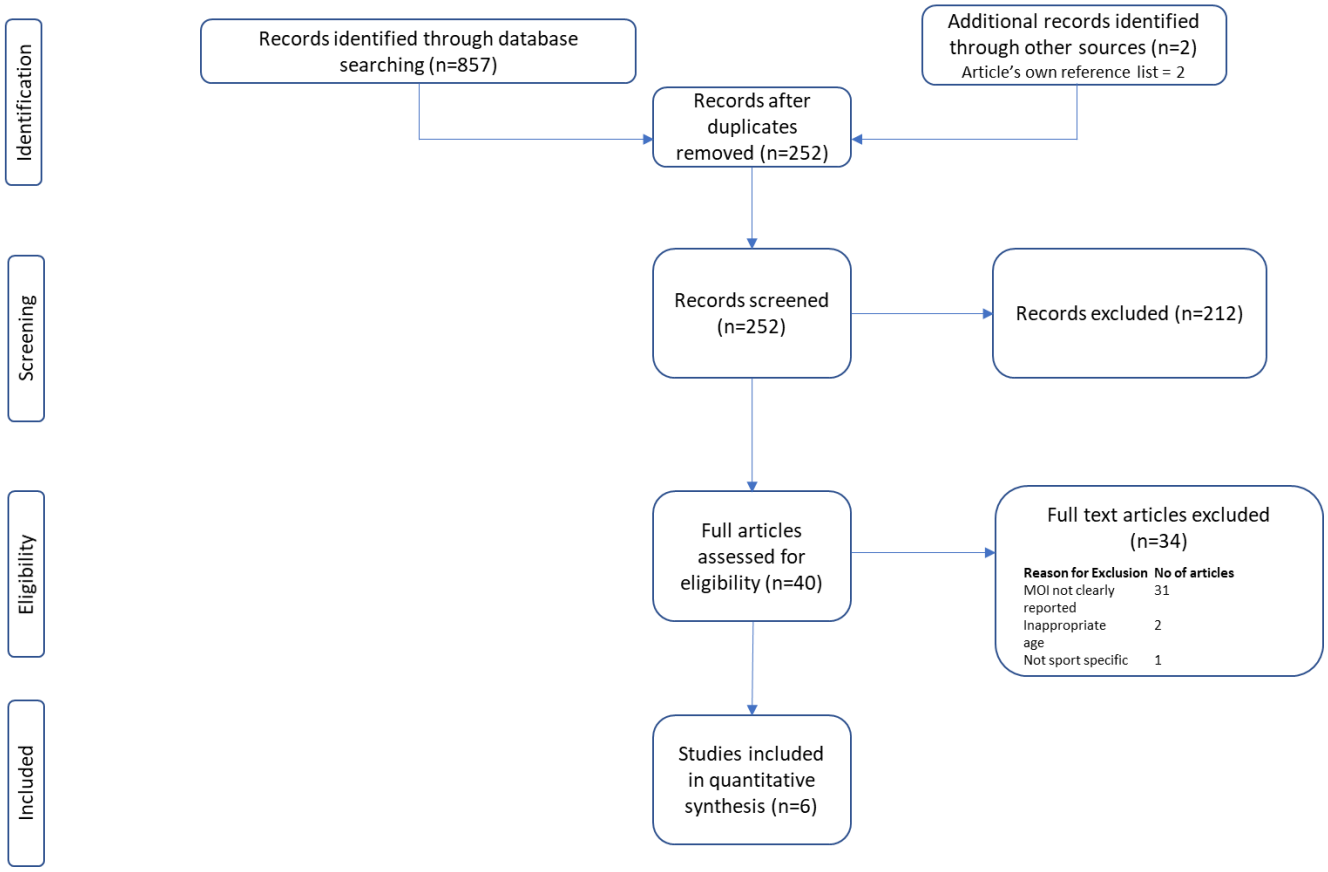

Figure 1. PRISMA flowchart

MOI = mechanism of injury

Of the six studies included in the review, one was retrospective in nature,[39] one was a mixed methodology of prospective and retrospective data,[29] three were prospective epidemiological studies [12,30,31], and one was a systematic video analysis.[26] Two studies sampled elite level players,[26,29] three studies sampled recreational level players,[12,31,39] and one study included both elite and recreational players.[30] The total number of participants in the papers were 11,401. There were 781 injuries, of all types, reported,

of which 118 (15.1%) were knee injuries. Only one study specified whether knee injuries were noncontact.[26] Playing position of the injured players was reported in three studies.[26,30,39] However, one study[12] reported general playing position (e.g. attack, centre, defence) rather than specific playing positions (e.g. C, GD, GA), with the exception of reporting that GD was the most common playing position of the injured players. One injured player eligible for inclusion in the analysis, played GA.[39] Of the 16 ACL injuries sustained in the video analysis study, [26] 10 played WA, three played C, two played GS, and one played WD.

Mean participant age ranged from 18 to 25 years although age of the entire cohort was not reported in two of the studies.[12,26] However, the mean age of the injured players was included in one study.[12] Other participant characteristics (height and mass) were included in three of the studies [29-31]; mean participant height ranged from 1.7 to 1.8 m; mean mass ranged from 63.6 to 75.6 kg.

Author	Study Design	Study Setting	Level of Participation	Study Size	Playing Position	Participant Characteristics	Situation of Injury	Mechanism of Injury
Stuelcken et al. (2016)	Systematic Video Analysis	Matches (league)	Elite	16 WA = 10, C = 3, WD = 1		--	Landing from a jump = 13/16 (81.3%) Attempting to receive or intercept a pass = 10/16 (62.5%) Running at medium-high intensity = 13/16 (81.3%) Performing a side-step cutting manoeuvre = 1/16 (6.3%) Landing from a jump of moderate-maximum capacity = 12/16 (75%) Overreaching to receive/intercept a pass = 3/16 (18.8%) Player incurred contact whilst in the air = 7/16 (43.8%) Unbalanced landing = 6/16 (37.5%) Loading predominantly on the side of injury = 13/16 (81.3%) Rapid braking to slow forward momentum = 4/16 (25%) Player incurred contact at/after landing = 3/16 (18.8%)	Knee at or close to full extension = 2/16 (12.5%) Apparent knee valgus collapse= 12/16 (75%) Hip internal roation on the injured side = 7/16 (43.8%) Trunk rotation away from side of injured knee = 11/16 (68.8%) Trunk lateral flexion towards side of injured knee = 7/16 (43.8%)
Hopper et al. (1995a)	Prospective Epidemiology S	Matches (league)	Recreational	Total = 11228 Injured = 608		Injured players age = 18.8 ±5.6 years	Incorrect Landing = 19 (38%) Player Contact = 12 (24%) Slip/stop = 11 (22%) Other = 8 (16%)	--
Chong & Tan (2004)	Retrospective Clinical Revie	Hospital	Recreational	Total = 259 Eligible = 1	GA	Age = 25 years	Awkward landing	--
Hopper & Elliott (1993)	Retrospective and Prospect	Tournament	Elite	75		Age = 23.7 ± 3.6 years Height = 173.5 ± 6.4 cm Mass = 66.2 ± 7.9 kg	Retrospective: Incorrect Landing = 24 Trodden on foot = 4 Player Contact = 11 Rebounding = 2 Slip/trip/stop = 24 Other = 33 Unable to accurately report as unclear which situation of injury	--
Hopper et al. (1995b)	Prospective	Matches (league)	Recreational	Total = 72 Injured = 52		*Age groups* **19 years** Mass = 65.2 ± 8.7 kg Height = 171.8 ± 6.8 cm **20-22 years** Mass = 64.2 ± 9.1 kg Height = 171.3 ± 6.3 cm **23+ years** Mass = 63.8 ± 7.9 kg Height = 170.0 ± 6.2 cm	applied to the players eligible for inclusion	--
Smith et al. (2020)	Prospective	Training or matches	Recreational	29		*Playing groups* **AMND** Age = 21 ± 4 years Mass = 75.6 ± 11.7 kg Height = 174 ± 0.08 cm **Reserves** Age = 21 ± 2 years Mass = 71.2 ± 13.7 kg Height = 174 ± 0.08 cm **Premiers** Age = 25 ± 4 years Mass = 72.8 ± 11.3 kg Height = 176 ± 0.06 cm	--	--

Table 3. Data from Studies Included in Quantitative Synthesis

AMND = Adelaide Metropolitan Netball Division

Players self-reported the situation of injury in five studies,[12,29-31,39] the only exception was the video analysis study[26] where the authors analysed video of the injury occurring and documented the situation and mechanism by observing the videos from all available angles. Situation of knee injury was specified in all but one study,[31] injuries were not separated by region by Smith et al.[31] but reported for all injuries. Furthermore, it was unclear which players suffered which situation of injury in one study[30] so those numbers were not included in the analysis. Players may have incurred more than one situation simultaneously. The most common situations of injury were landing (46.6%),[12,26,29,39] slipping/tripping/sudden stopping (34.7%),[12,26,29] player contact (28%),[12,26,29] treading on foot (3.4%),[12,26,29,30] rebounding a shot (1.7%),[12,26,29] or other (48.3%).[12,26,29] Player contact was not specified relative to where contact occurred (e.g. leg, trunk, etc.).[12,26,29]

In the video analysis study, [26] 13 (81.3%) of the ACL injuries reviewed occurred when landing from a jump. Of the 13 injuries, the type of landing included split-landing (46.1%), leap-landing (38.5%), hop-landing (7.7%), and single-leg landing (7.7%). Therefore, the majority of landings (53.9%) were different types of single-leg landings.[26] Half of the injuries in the video analysis[26] were indirect contact and half were noncontact.

Only one study[26] considered mechanism of injury. Mechanism of injury in the video analysis[26] was reported as one of or a combination of the following: knee at or close to full extension (12.5%), apparent knee abduction collapse (75.0%), and hip internal rotation on the injured side (43.8%). Players sustained knee injuries due to a combination of the above situations and mechanisms. The position of the trunk was also noted to be important [26]; 11 players (68.8%) were observed to rotate the trunk away from the side of the injured knee whereas seven players (43.8%) laterally flexed the trunk towards the side of the injured knee.

DISCUSSION

The purpose of this systematic review was to identify the situations and mechanisms of noncontact knee injury in netball. However, due to inadequate reporting of the mechanism of injury, this purpose could not be fulfilled. Knee injuries accounted for 15.1% of all injuries within the studies included in the analysis, the findings are similar to those previously reported with rates between 14 and 18%.[11,14,20,40] It was hypothesised that the most common situation of injury would be landing while catching the ball. The results partially support the hypothesis because the predominant situation of injury was landing (46.6%) but it was not always clear if players were trying to catch a ball. It was also hypothesised that the most common mechanism of injury would be knee abduction motion. The results support the hypothesis because three-quarters of injuries occurred with a knee abduction collapse. However, mechanism of injury was only adequately reported in one study[26] so these results should be interpreted with caution. However, the mechanisms of injury reported by Stuelcken et al.[26] are similar to those in studies on female athletes in other court sports. [23,24,33,41]

The most common specified situation of injury was landing which can occur when a player is attacking or defending and is consistent with previous research in female athletes sustaining noncontact ACL injuries in other sports. [23,24,33,41] However, the studies included in this review did not specify whether such injuries were noncontact in nature. The majority of studies were large scale epidemiological studies designed to investigate the most common injuries in netball[12,29,30] where identification of the mechanism of injury was a secondary goal and was self-reported. The self-report method risks incomplete or inadequate data because it relies on participants' memory, or the memory of others, both of which may be inaccurate.[42-44] It is also important to consider whether there was any bias from the clinicians gathering the data and if they

asked leading questions to the participants who may have been unsure how they sustained the injury.[44] Whilst there are some limitations in the studies published to date, landing is consistently the most identified situation of injury regardless of the way that injury situations were documented.[12,26,29-31,39] Because landing is the most identified situation of injury, there is a need to include landing training in injury prevention programmes for netball players. Landing training should incorporate both double- and single-leg landings[26] and include consideration of the ideal landing position[45] defined as head upright, shoulders level, trunk strong, upright, and controlled, feet shoulder width apart, hips and knees bent to 45º, knees in line with toes, and soft landing.[45] Furthermore, landing training should also include match situation simulations involving opponents contesting the ball in ways that reflect the indirect contact that occurs in around half of all ACL injuries.[24]

The second most common situation of injury was sudden stopping, slipping, and tripping.[12,29,30] Such situations reflect the nature of the game due to the relatively limited space in which players compete while being closely marked by an opponent.[46] Coaches and practitioners should ensure that netball-specific injury prevention training includes exercises that reflect the close-quarters nature of the game, the footwork rule,[47] and the need to suddenly stop and control high braking forces.[1] Player contact was identified in less than a quarter of the cases but is something that must be considered because of the rules of the game where it is permitted to contest for the ball.[47] Although studies did not specifically report where contact occurred prior to injury being sustained,[12,26,29-31] given the nature of the game it is reasonable to assume that contact most likely occurred to the trunk rather than directly to the knee. Injuries reporting direct contact with the knee were also not included in the analysis. Coaches and practitioners should therefore include drills or exercises involving external

perturbations applied to the trunk or shoulder while encouraging a more favourable landing position.

The most commonly observed mechanism of injury was apparent knee abduction collapse[26] which is consistent with reported mechanisms of noncontact ACL injuries in female athletes in other agility sports.[23,24,33,41] In almost half of the cases there was also hip internal rotation observed.[26] The one study that documented the mechanisms of injury included both noncontact and indirect contact ACL injuries.[26] Therefore, it is not possible to identify how many of the noncontact knee injuries were sustained through the mechanisms listed in Table 2. However, given the findings from Stuelcken et al.[26] alongside established mechanisms of noncontact knee injuries in female athletes,[23,33,41] it is reasonable to conclude that the mechanisms listed in Table 2 place netball players at increased risk of noncontact ACL injury. Therefore, netball-specific injury prevention programmes should be designed to help players control the position of their hip and knee in a way that limits excessive hip internal rotation and knee abduction displacement, and encourages greater knee flexion, respectively.

In the sequence of prevention of sports injuries[21,22,34], the first step is a thorough understanding of the extent of the problem including the incidence and severity of injury. In netball, the incidence and severity of injury has been well reported and has remained relatively unchanged over several years[10-15]. Establishing the mechanism of injury is part of the second step in the injury prevention sequence,[21,22,34] and the purpose of this systematic review was to gain an understanding of the mechanism of noncontact knee injury in netball. Specifically identifying the situations and mechanisms of noncontact knee injury in netball informs authors and practitioners about the situations ‘of risk’ for such an injury in this specific sport. A greater understanding of the situations and mechanisms of netball-specific noncontact knee injury can then facilitate

389 a more informed approach to the design of appropriate injury prevention programmes.
390 Such programmes form the third step of the sequence of injury prevention.[21,22,34] Injury
391 prevention programmes have been devised[48,49] based around a limited knowledge of
392 the situations and mechanisms of noncontact knee injury in netball.
393 Both programmes[48,49] contain training components (e.g. strength training, balance
394 training, plyometric training) which have been shown to help reduce ACL injuries in
395 female athletes.[50] However, more specific programme design considerations may be
396 needed for netball given the unique nature of the sport and the rules that govern it.
397
398 The position of the trunk on landing is an important consideration due to its effect on
399 knee position on landing and injury risk.[51-53] Lateral flexion of the trunk contributes to an
400 ipsilateral knee abduction moment and imposes strain on the ACL.[41] The involvement
401 of the trunk and upper limbs is pertinent in netball due to the need to catch and defend
402 the ball, which was identified as the specific situation at the time of injury in one
403 study.[26] The authors also identified the alterations in trunk alignment that occurred after
404 ground contact including trunk rotation away from the injured side along with lateral
405 flexion towards the side of injury.[26] A further consideration is the footwork rule and how
406 this can influence injury risk.[54] In particular there is a need to rapidly reduce horizontal
407 momentum using a large braking force.[26] Such a task creates a large external flexion
408 moment at the knee which needs to be balanced by an internal knee extension
409 moment produced by the quadriceps and potentially leading to increased strain on the
410 ACL.[55] Quadriceps activity also causes anterior tibial shear forces which can further
411 strain the ACL particularly when the knee is close to full extension.[26] If high internal
412 knee extension moments are combined with landing on a knee at close to full extension
413 (as was identified as one of the mechanisms of injury [26]), this generates high anterior
414 tibial shear forces which can, in turn, threaten the ACL.[56] Thus, both trunk position and
415 the high braking forces induced because of the footwork rule need to be considered

and inform the design of netball-specific noncontact knee injury prevention programmes.

We applied language restrictions within our search strategy. Such a restriction excludes studies in other languages. Future systematic reviews could search other language databases to identify other worldwide works that identify situation and mechanism of injury in netball. We did not include any subgroup analysis such as level of athlete in our analysis. Such an analysis would help to identify any differences in players competing at different levels. Future research could compare situations and mechanisms of noncontact knee injury in players at both the elite and recreational level.

Based on the findings in this review, it is apparent that previous literature investigating netball noncontact knee injury has not adequately reported the situation and mechanism of injury to date. It is recommended that future research focuses on noncontact knee injuries specifically and reports both the situation and mechanism of injury in accordance with appropriate operational definitions.[26] This should be done at both recreational and elite levels to investigate any variations at different levels of competition so that appropriate intervention strategies can be designed and implemented.

CONCLUSION

Situations and mechanisms of noncontact knee injury in netball have not been adequately reported to date. The most common situation of knee injury appears to be landing, and the most common mechanism of injury is a knee abduction collapse. However, most existing studies do not clearly report whether knee injuries are

noncontact or indirect contact in nature. The optimal design of netball-specific noncontact knee injury prevention programmes requires adequate information about the most common situations and mechanisms of noncontact knee injury. Future studies should seek to better report the detail about the situations and mechanisms of netball noncontact knee injury.

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Mechanism and Situation of Injury Data Extraction Document

Authors	Year of Publication	Study Characteristics		Situation						Mechanism					Notes
				Landing	Running (sudden stop/cutting)/slipped/tripped	Trodden on foot	Rebounding	Player contact	Other	Apparent knee valgus collapse	Knee at or close to full extension	Hip IR (on injured side)	Trunk rotation relative to injured side	Trunk lateral flexion relative to injured side	
		Study design	Cross-sectional observational												
		Study setting (training, match)	Championships (matches)												
		Level of participation	Open and U/21 All Australia National Champs												
		Study Size (n)	n=228 (retrospective); n=52 (prospective)												
		Injured player's team position	not documented												
		Participant characteristics	Open (n=75) 23.7 +/- 3.6yrs; 173.5+/-6.4cm; 66.3+/-7.9kg. U-21 (n=78) 19.2+/-2.2yrs; 173.1=/-5.8cm; 66.9=/-7.3kg												
		Injuries (retrospective)	Open: R knee n=21, L knee n=14. U-21: R knee n=20, L knee n=8.	24	24	4	2	11	33						Did not include % from table II as those stats include U-16. Not specifically noncontact injury
Hopper & Elliott	1993	Injuries (prospective)	Knee n=9 (17.3%). 2 players sustained ACL and required surgery (unknown which age group)	0	0	0	0	0	0	MOI not linked to specific injury					MOI not linked to specific injury
		Study design	Cohort (prospective observational)												Unable to specify which players suffered which situation of injury
		Study setting (training, match)	Matches and training (none reported from training)												
		Level of participation	Grades A1-6 Western Australia (sub-elite)												
		Study Size (n)	n=72												
		Injured player's team position	not documented												
		Participant characteristics	Age: 20.6+/-3.6yrs; Height: 170.9+/-6.3cm; Mass: 64.7+/-8kg												Includes 15-18yr olds
Hopper & Elliott	1995	Injuries	Knee n=4	2	2	0	0	0	0	MOI not included					2 injuries in 15-18 year age group
		Study design	Cross-sectional												
		Study setting (training, match)	Hospital - data on those undergoing ACLR												
		Level of participation	School n=3; recreational n=1												
		Study Size (n)	Netball n=4 (Total female n=13)												Total=259 cases (M & F)
		Injured player's team position	GA												
		Participant characteristics	1 x 13yrs; 1 x 14 yrs; 1 x 17yrs; 1 x 25yrs												
Chong & Tan	2004	Injuries	ACL	4	0	0	0	0	0	MOI not included					Termed as 'awkward landing'. Only 1 over-18
		Study design	Cohort (prospective observational)												
		Study setting (training, match)	Matches only												
		Level of participation	Recreational												
		Study Size (n)	n=11228 total players; n=608 injuries												
		Injured player's team position	Attack=38.5%; Centre=18.6%; Defence=42.4%. GD most common												
		Participant characteristics	not documented												
Hopper, Elliott & Lalor	1995	Injuries	ACL=11 (1.8%); Meniscus=16 (2.6%); MCL=9 (1.5%); LCL=6 (1%); Patellar sublux/dislocated=8 (1.3%)	19	11	0	0	12	8	MOI not included					
		Study design	Systematic video analysis												#Provides multiple other situations that occurred; players displayed multiple factors
		Study setting (training, match)	Matches												Running at medium-high intensity=13
		Level of participation	Elite (ANZ Championships & U-21 international tournament)												Injury occurred whilst performing a side-step cutting manoeuvre=1
		Study Size (n)	n=16												Injury occurred whilst landing from a jump=13
		Injured player's team position	WA x 10, C x 3, GS x 1, WD x 1												Landing from a jump of moderate-maximum capacity=12
		Participant characteristics	not documented												Overreaching to receive/intercept a pass=3
Stuelcken et al.	2015	Injuries	ACL (all noncontact (8) or indirect contact(8))	6*	4^	0	0	10[a]	#	12	2	7	11	7	*Used term 'unbalanced landing'. ^Used Term 'rapid braking to slow forward momentum. [a]Includes player incurring contact in the air and at/after landing. Loading predominantly occurring on the side of the injured knee=13
		Study design	Prospective observational												Trunk rotation (transverse plane) away from the side of the injured knee before the landing was completed=11
		Study setting (training, match)	Training and matches												Trunk lateral flexion (frontal plane) towards the side of the injured knee before the landing was completed=7
		Level of participation	Community												
		Study Size (n)	n=269, (n = 29 for >18, excluding "Seniors" division)												
		Injured player's team position	not documented												
		Participant characteristics	Adelaide Met Netball Division: 21 +/- 4 years, 75.6 +/- 11.7 kg, 1.74 +/- 0.08 m; Reserves: 21 +/- 2 years, 71.2 +/- 13.7 kg, 1.74 +/- 0.08 m; Premier: 25 +/- 4 years, 72.8 +/- 11.3 kg, 1.76 +/- 0.06 m												
Smith et al.	2020	Injuries	Knee: Adelaide Met - 2.9/1000 exposure hours (n=3 out of 10 total) , Reserves - 2.29/1000 exposure hours (n = 2 out of 8 total).	27%				28%	22%	MOI not included					Situation percentages given for all injuries, not specific to injury region