The Epidemiology of Injury and Illness at the Vitality Netball World Cup 2019: An observational study

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ABSTRACT

Background: Netball is a physical game with sudden changes of direction, decelerations, jumping and landing, stop/start manoeuvres and restrictive footwork rules exposing players to injury. Close contact play and shared facilities during tournaments, increase illness risk.

Objective: To describe the incidence, period prevalence, types and severity of injuries and illnesses during the 10-day Vitality Netball World Cup 2019 (NWC).

Methods: All players from 16 teams consented (n=192). Medical staff recorded injuries (840 exposure hours), illnesses (1440 player-days) and time-loss. Main outcome measures included incidence (I) calculated as injury/1000 player-hours and illness/1000 player-days, period prevalence (PP) and severity (time-loss) of all match injuries and illnesses.

Results: 39 players sustained 46 match injuries (I=54.76; PP=20.31%). Lower limb injuries (I=29.76), specifically the ankle (I=13.10) were most common with lateral ankle ligament sprains the highest

(I=17.39). Contact injuries (I=40.48) significantly exceeded non-contact injuries (I=14.29; p=0.0124). Centre players sustained most injuries (n=12; 26%; I=14.29), followed by goalkeepers (n=10; 22%; I=11.90) and goal defenders (n=8; 17%; I=9.52). Injuries occurred in almost 50% of matches, and 67% did not result in time-loss. Time-loss injuries (n=14; 33%) were most frequent in the lower limb (n=10; 71%) specifically involved lateral ankle ligaments (n=4; 29%), attributable to contact (n=11; 79%) and mostly implicated centre players and goal defenders (n=4 each; 29% each). 11 players contracted 11 illnesses (I=7.64; PP=5.72%) with respiratory tract illness contributing 36%. Most illnesses did not result in time-loss (91%).

Conclusion: This is the first study reporting injury and illness during an NWC. Contact was the main mechanism of injury, and 2/3 of injuries did not result in time-loss. The ankle is most commonly injured and centre players sustain most injuries. Non-respiratory system disease was most frequent, but upper respiratory tract infection remains the most common diagnosis. Urgent, targeted surveillance studies using similar methodology are required to develop injury and illness preventative strategies in elite netball.

Keywords

netball, epidemiology, severity, injuries, illness, clinical characteristics

Clinical Implications:

1. The most common mechanism of injury involved contact (73.9%), primarily with an opposition player (91.2%).
2. Injuries involve mostly the lower limb (54% of all injuries), and specifically lateral ankle ligament sprains (17.4% of all injuries).
3. Injuries are mostly sustained by centre players (26%), goalkeepers (22%) and goal defenders (17%).
4. Only 1/3 of injuries resulted in players not being able to compete in consecutive matches. The lower limb (71%) specifically the ankle (29%) was mostly involved. Contact was the main

mechanism of injury (79%), and centre players and goal defenders mostly implicated (29%each).

5. Upper respiratory tract illness (36%) remains the most common diagnosis.
6. More studies applying the same methodology are required to provide insight on injury and illness in elite netball players and to develop appropriate prevention strategies.

INTRODUCTION

Netball was first played in England in 1895 and its popularity continues to grow in many Commonwealth countries [1]. The game of netball attracts mostly females and comprises a team of 7 players contesting against an opponent team in close contact play. At an international level, a netball game lasts 60 minutes consisting of 4 x 15 minute quarters. The International Netball Federation (INF) Netball World Cup (NWC) is a quadrennial international world championship with the inaugural tournament hosted in Eastbourne, England, in 1963 [1]. Sixteen teams contested the 15th staging of this premier competition in the Vitality Netball World Cup 2019 (NWC2019) [2]

Netball is a physical game that requires muscular endurance, as well as bursts of intense activity and sudden changes of direction, multiple jumping and landings and rapid acceleration and deceleration, exposing players to injury [3, 4]. While netball initially started as a non-contact game, it has evolved into a sport that promotes a degree of physicality between players contesting for the ball, which increases the likelihood of injury [5, 6, 7, 8].

Injury and illness surveillance during the Olympic Games showed that 11% and 7% of the athletes incurred at least one injury or illness, respectively, but the incidence varied widely among sporting disciplines [9, 10, 11]. Netball is not part of the Olympic Games sporting codes, and there is a lack of injury and illness surveillance in elite netball. There are some data available on sub-elite (provincial, interstate, inter-district, university and club level) players [6, 12, 13, 14, 15, 16].

Across various levels of competition, the types of injuries are similar [8, 17]. The ankle and knee are the most commonly reported body areas [8, 13, 15, 18, 19], with ankle sprains a problem at all levels of competition [17, 20, 21]. The most common pathology types are ligament sprains, muscle strains and contusions [8, 15, 19]. Incorrect landing and contact with another player are the most common mechanisms of injury reported [8, 15, 19].

Illness can cause a reduction in exercise performance and contribute extensively to absence from match and training days, potentially causing a notable burden on teams to stay competitive [22]. Similar to other competitions, e.g. the Olympic Games, netball players share rooms, bathrooms and eat in the same dining hall, which may cause a risk of illness contraction. Previous studies also showed that female athletes are at a significantly higher risk of contracting illness compared to male athletes [23, 24, 25].

The growing interest in netball as a sport, and the desire of national teams to become more competitive, means that the compilation and analysis of injury and illness data are increasingly important. There is no injury and illness surveillance data for the most prestigious event in global netball. This study aims to describe the incidence, period prevalence, types and severity of injuries and illness in elite netball players during the international NWC2019 tournament played in Liverpool, England.

METHODS

Study design and ethical concerns

An observational study that involved data collection during the NWC2019 tournament held from 12–21 July 2019 at the M&S Bank Arena in Liverpool, England. All participants received information regarding the study before the start of the tournament and gave consent for the usage of their data for research. The injury and illness surveillance forms followed both the international consensus statement on definitions and methods of data recording and reporting [26, 27] and the injury and illness prevention studies of the International Olympic Committee (IOC) as described in detail in previous publications [10, 27]. The INF approved the conduction of the study and the Health Sciences Ethics Committees of the University of Pretoria (REC466/2019) provided ethical clearance.

Participants and demographics

Sixteen netball teams (squad size limited to 12 players/team; n=192) contested the NWC2019 tournament. Once the tournament started, teams could not exchange or replace listed players of the squad with additional players. Five teams automatically qualified by their position in the INF world rankings, and England qualified as the host nation. The remaining ten teams qualified via regional qualification tournaments, with two teams selected from each of the five international netball regions: Africa, Americas, Asia, Europe and Oceania [1]. The event took place over a total of 10 days whereby every team played a minimum of 7 matches and the top 4 teams played 10 matches. Players presenting with an injury or illness during the tournament were seen by their team physician or the venue medical officer. Countries that participated in the NWC2019 included: Australia, Barbados, England, Fiji, Jamaica, Malawi, New Zealand, Northern Ireland, Samoa, Scotland, Singapore, South Africa, Sri Lanka, Trinidad and Tobago, Uganda and Zimbabwe.

Data Collection

The recording of injuries and illness could be completed on paper or electronically. We did not depend on player feedback to record data as each team had either their own team physician or one of the venue medical doctors recording the data during or after each match. The injury and illness surveillance forms provided basic demographic information (country and age). We reported the results in the injury and illness categories according to the IOC consensus statement [28]. We logged the frequency of match injuries for the following main categories: main anatomical body region; specific body area; tissue type and pathology; and severity of injuries i.e. days lost (0 days, 1–7 days, 8–28 days, >28 days). We additionally reported on the type of contact and phase of play; specific position of play and combined position groups [shooters (GA, GS), centre court (WA, C, WD), defenders (GK, GD)]; and frequency of injuries per match. We recorded the frequency of illness for all tournament days in the following main categories: main organ system and diagnosis of illness; aetiology of illness (infective vs. non-infective); and severity (≥1 day time-loss). Only involved body areas are reported. No imaging or special investigations were used to confirm clinical diagnoses of injury or illness.

Definitions

a) An injury e.g. ankle ligament sprain was defined as *'any newly acquired injury as well as exacerbations of pre-existing injury that occurred and required medical attention from the team physician or venue medical doctor during competition'* [27, 29].

b) An illness e.g. sinusitis was defined as *'any physical complaint (not related to injury), symptom or sign presenting in a player that required medical attention from the team physician or venue medical doctor on a specific day'* [10].

c) Recurrent injury or illness refers to *'a player that is available for training and competition after recovering successfully from the index injury or illness and then presents with the same injury or illness'* [28].

d) Severity is defined as *'the number of days that have lapsed from the day after the onset of the incident to the day the athlete returns to full participation in training or competition'* [28].

e) Time-loss was defined as *'any medical encounter requiring medical intervention resulting in a loss of match play of ≥1 day'* [10].

Statistical Data Analysis

Descriptive statistics reported the incidence (I) and 95% Confidence Intervals (95%CI) [30] of all injury and illness data. Inferential statistics determined if a significant difference existed at the 5% level. We applied the Chi-square Goodness of Fit test for the categorical variables in those instances where the different categories being compared had at least 5 observations (i.e. contact vs. non-contact injuries, differences between position groups and frequency of injuries per match). In cases where significant differences were found, post hoc tests were performed with Bonferroni adjustments.

Calculation of player exposure

a) For each team the number of matches played and dates the tournament finished were different, depending on team performance and if a team was able to advance to the play-offs and placing matches. On the last day of the tournament, only 8 teams were available for injury and illness surveillance [28].

b) For injury, the match player-hours for one team was calculated as: one netball match of 60min (1 hour of play), multiplied by 7 players/team = 7 match player-hours/team/match. We assumed that 7 players per team started and completed the match, regardless of whether a player was substituted [28].

c) For illness, the total player-days were calculated as: the total tournament-days during the 10-day event period, for each team × daily squad size (12 players per team per day) [28].

d) For severity, the number of days lost due to injury and/or illness was estimated based on the substantive clinical experience of the attending medical officer at the time of entry of the data. The short period of the tournament made accurate follow-up information on the player's condition and actual recording of the return-to-play date difficult. Severity time bins applied were: 0 days, 1–7 days, 8–28 days, >28 days [28].

e) Time-loss: the proportion (%) of injury or illness resulting in ≥1 days lost [26].

Measures of outcome

The proportion of an injury or illness (frequency) was calculated as the percentage (%) of the total injuries or illnesses during the tournament. The incidence (I) of match injuries is expressed as the number of match injuries per 1000 match player-hours, and the incidence (I) of illness as the number of illnesses per 1000 player-days. We recorded two injuries or illnesses in the same player as separate injuries, and both new and recurrent injuries and illnesses were included in the incidence reports [28]. Period prevalence was calculated as a percentage (%) of the total players that sustained an injury or contracted an illness during the tournament.

RESULTS

Data recording were completed on paper in 80% of cases and via the electronic system in 20% of cases.

Demographics of study participants

For all players, the mean age was 26.57 years (95%CI: 25.88-27.27) and the mean height was 177.25cm (95%CI: 175.87-178.63).

Epidemiology of injuries in netball players

During the 10-day tournament, 840 match player-hours were recorded for 192 players. A total of 46 match play injuries were sustained in 39 players calculating to an injury incidence of 54.76/1000 player-hours (95%CI: 38.94-70.59) and period prevalence of 20.31%.

Body region (with specific body area), and clinical diagnosis

Evaluating the main body regions and body areas in Table 1, the lower limb was most frequently involved (n=25; 54.35%; I=29.76, 95%CI: 18.10-41.43) followed by the head and neck (n=10; 21.73%; I=11.90, 95%CI: 4.53-19.28) and the upper limb (n=7; 15.22%; I=8.33, 95%CI: 2.16-14.51). In the lower limb, ankle injuries occurred more often (n=11; 23.91%), than lower leg (n=5; 10.87%) and knee (n=4; 8.70%) injuries. Lateral ankle ligament sprains (17.39%) and finger sprains (8.7%) were the most common clinical diagnoses.

Tissue type involvement is depicted in online Supplementary Table S1. The superficial tissue/skin was most frequently involved (n=20; 44.44%; I=23.81, 95%CI: 13.37-34.24), followed by ligament/joint capsule (n=13; 28.88%; I=15.48, 95%CI: 7.06-23.89) and muscle/tendon (n=7; 15.55%; I=8.33, 95%CI: 2.16-14.51). Contusions were the most common (n=20; 44.44%), followed by joint sprains (n=13; 28.88%), and muscle injury (n=6; 13.33%).

Table 1: Injuries by body region, body area, and clinical diagnosis

Main body region		Body area and clinical diagnosis[#]	n	% of all injuries	Incidence per 1000 player-hours (95%CI)
All Injuries			**46**	**100.00**	**54.76 (38.94 - 70.59)**
	All Head & Neck		**10**	**21.73**	**11.90 (4.53 - 19.28)**
		All Head	**8**	**17.39**	**9.52 (2.92 - 16.12)**
		Brain/Spinal cord injury	2	4.35	**
		Contusion (superficial)	4	8.70	**
		Injury without tissue type specified	2	4.35	**
		All Neck	**2**	**4.35**	**
		Contusion (superficial)	2	4.35	**
	All Upper Limb		**7**	**15.22**	**8.33 (2.16 - 14.51)**
		All Upper arm	**1**	**2.17**	**
		Contusion (superficial)	1	2.17	**
		All Elbow	**1**	**2.17**	**
		Contusion (superficial)	1	2.17	**
		All Hand	**5**	**10.70**	**5.95 (0.73 - 11.17)**
		Finger sprain	4	8.70	**
		Contusion (superficial)	1	2.17	**
	All Trunk		**4**	**8.70**	**
		All Chest	**1**	**2.17**	**
		Contusion (superficial)	1	2.17	**
		All Thoracic Spine	**1**	**2.17**	**
		Contusion (superficial)	1	2.17	**
		All Lumbosacral	**1**	**2.17**	**
		Contusion (superficial)	1	2.17	**
		All Abdomen	**1**	**2.17**	**
		Contusion (superficial)	1	2.17	**
	All Lower Limb		**25**	**54.35**	**29.76 (18.10 - 41.43)**
		All Hip/groin	**2**	**4.35**	**
		Muscle injury	1	2.17	**
		Contusion (superficial)	1	2.17	**
		All Thigh	**3**	**6.52**	**
		- posterior	1	2.17	**
		Muscle injury	1	2.17	**
		- anterior	2	4.35	**
		Contusion (superficial)	2	4.35	**
		All Knee	**4**	**8.70**	**
		- lateral	3	6.52	**
		Contusion (superficial)	1	2.17	**
		Muscle injury	1	2.17	**
		Meniscal injury	1	2.17	**

		- medial	1	2.17	**
		Joint sprain (ligament tear or acute instability episode)	1	2.17	**
		All Lower leg	**5**	**10.87**	**5.95 (0.73 - 11.17)**
		- posterior (incl. Achilles tendon)	2	4.35	**
		Tendon injury	1	2.17	**
		Muscle injury	1	2.17	**
		- anterior	3	6.52	**
		Contusion (superficial)	1	2.17	**
		Muscle injury	2	4.35	**
		All Ankle	**11**	**23.91**	**13.10 (5.36 - 20.86)**
		- lateral	11	23.91	13.10 (5.36 - 20.86)
		Contusion (superficial)	2	4.35	**
		Ligament sprain	8	17.39	9.52 (2.92 - 16.12)
		Missing	1	2.17	**

n: number of injuries reported

Missing data n=1 for tissue type

%: frequency of injuries reported in the study

I: Incidence per 1000 player-hours

95%CI: 95% Confidence Intervals

Only involved body areas are reported

**Number too small to calculate incidence accurately (incidence and 95%CI only reported for n≥5)

Mechanism of injuries

Table 2 illustrates the mechanism of injury. The incidence of contact injuries (I=40.48, 95%CI: 26.87-54.08) was significantly higher compared to non-contact injuries (I=14.29, 95%CI: 6.20-22.37; p=0.0124). Most of the contact injuries were due to contact with a player of the opposing team (n=31; 91.18%; I=36.90, 95%CI: 23.91-49.90) and quarters 1, 2 and 3 had similar numbers of contact injuries as well as non-contact injuries with quarter 4 slightly less for both.

Table 2: Mechanism of netball injuries (contact vs. non-contact) and the phase of play when it occurred (% of all injury)

Cause	Type of contact	n (46)	%	Incidence per 1000 player-hours (95%CI)	p-value
Contact		**34**	**73.91**	**40.48 (26.87 - 54.08)**	0.0124*
	With player of opposing team	31	91.18	36.90 (23.91 - 49.90)	
	With player of own team	1	2.94	**	
	With stagnant object (e.g. sign board, post)	1	2.94	**	
	Violation of rules (foul play)	1	2.94	**	
	Phase of play	**34**	**100**	**40.48 (26.87 - 54.08)**	
	Quarter 1	6	17.65	7.14 (1.43 - 12.86)	
	Quarter 2	7	20.59	8.33 (2.16 - 14.51)	
	Quarter 3	8	23.53	9.52 (2.92 - 16.12)	
	Quarter 4	4	11.76	**	
	Missing	9	26.47		
Non-contact		**12**	**26.09**	**14.29 (6.20 - 22.37)**	
	Non-contact trauma	7	15.22	8.33 (2.16 - 14.51)	
	Other combined non-contact	5	10.87	7.14 (1.43 - 12.86)	
	Gradual onset	1	2.17	**	
	Recurrence of previous injury	2	4.35	**	
	Other	2	4.35	**	
	Phase of play	**12**	**100**	**14.29 (6.20 - 22.37)**	
	Quarter 1	3	25.00	**	
	Quarter 2	2	16.67	**	
	Quarter 3	4	33.33	**	
	Quarter 4	1	8.33	**	
	Missing	2	16.67		

n: number of injuries reported

%: frequency of injuries reported in the study

I: Incidence per 1000 player-hours

95%CI: 95% Confidence Intervals

*Significant differences between contact and non-contact - using Chi-square test

**Number too small to calculate incidence accurately (incidence and 95%CI only reported for n≥5)

Specific position and combined position groups for common injuries

As illustrated in Table 3, centre players sustained the most injuries (n=12; 26.09%; I=14.29, 95%CI: 6.20-22.37), followed by the goalkeepers (n=10; 21.74%; I=11.90, 95%CI: 4.53-19.28), and the goal defenders (n=8; 17.39%; I=9.52, 95%CI: 2.92-16.12). There was no significant difference in the incidence of injuries sustained when combining playing positions into shooters, centre court and defenders (p=0.0849).

Table 3: Specific position of play and combined position groups for injuries reported (% of all injuries)

Specific position of play	**n (45)**	**%**	**Incidence per 1000 player-hours (95%CI)**	**p-value**
Goal Shooter (GS)	3	6.52	**	
Goal Attack (GA)	5	10.87	5.95 (0.73 - 11.17)	
Wing Attack (WA)	5	10.87	5.95 (0.73 - 11.17)	
Centre (C)	12	26.09	14.29 (6.20 - 22.37)	
Wing Defence (WD)	2	4.35	**	
Goal Defence (GD)	8	17.39	9.52 (2.92 - 16.12)	
Goalkeeper (GK)	10	21.74	11.90 (4.53 - 19.28)	
Combined position groups†				
Shooters (GA, GS)	8	17.78	9.52 (2.92 - 16.12)	0.0849
Centre Court (WA, C, WD)	19	42.22	22.62 (12.45 - 32.79)	
Defenders (GK, GD)	18	40.00	21.43 (11.53 - 31.33)	

Missing data for n=1 injury

n: number of injuries reported

%: frequency of injuries reported in the study

I: Incidence per 1000 player-hours

95%CI: 95% Confidence Intervals

†As the counts for specific positions were too low, we grouped the positions together in Shooters (GA, GS), Centre Court (WA, C, WD) Defenders (GK, GD)

Frequency of injuries per match

There were 46 injuries sustained in the 60 tournament matches played, translating to 0.77 (95%CI: 0.66-0.87) injuries per match. In 46.67% of matches, there were no injuries while there was at least one injury in 53.33% of matches (Table 4).

Table 4: Frequency of netball injuries per match reported (% of all injuries)

Number of injuries/match	Matches n (60)	% injuries per match	p-value
No Injuries	28	46.67	0.6056[a]
At least one injury	32	53.33	
One Injury	23	38.33	
More than one	9	15.00	

n: number of matches

%: frequency of injuries reported in the study

a: No injury vs. At least one injury, p=0.6056

Severity of injuries (missing data for n=4 injuries)

Two-thirds of injuries did not cause any days lost from tournament play (n=28; 66.67%; I=33.33, 95%CI: 20.99-45.68) compared to combined days (≥1 to 28 days) of absence (n=14; 33.33%; I=16.67, 95%CI: 7.94-25.40; p=0.0308). Time-loss injuries are displayed in Table 5. The lower limb accounted for 71.43% (n=10) of time-loss injuries. Most time-loss injuries were sustained in the ankle (n=5; 35.71%) followed by the knee and thigh (n=2 each; 14.29% each). Eleven (78.57%) time-loss injuries, all of minor severity, were due to contact. The moderate and severe time-loss (>7 days; n=2; 14.29%) were encountered from non-contact injuries. Centre players and goal defenders sustained the most time-loss injuries (n=4 each; 28.57% each) Only 2 from the total of 42 injuries (4.76%) resulted in time-loss of more than 7 days.

Table 5: Time-loss injury detail

Severity	Body area and clinical diagnosis	n=14 (% time-loss injury)	% of total injury (n=42)	Contact	Player position
Minor (1–7 days)		**12 (85.71)**	**28.57**		
	Neck contusion	1 (7.14)	2.38	Yes	GS
	Upper arm contusion	1 (7.14)	2.38	Yes	Missing
	Elbow contusion	1 (7.14)	2.38	Yes	GA
	Thoracic Spine contusion	1 (7.14)	2.38	Yes	C
	Thigh				
	- posterior muscle injury	1 (7.14)	2.38	No	WA
	- anterior contusion	1 (7.14)	2.38	Yes	GD
	Knee				
	- lateral meniscal injury	1 (7.14)	2.38	Yes	GD
	- medial joint sprain	1 (7.14)	2.38	Yes	GK
	Ankle				
	- lateral contusion (superficial)	1 (7.14)	2.38	Yes	C
	- lateral Ligament sprain	3 (21.43)	7.14	Yes (x3)	GD, GS, C
Moderate (8–28 days)		**1 (7.14)**	**2.38**		
	Ankle				
	- lateral ligament sprain	1 (7.14)	2.38	No	C
Severe (>28 days)		**1 (7.14)**	**2.38**		
	Lower Leg				
	- Achilles tendon rupture	1 (7.14)	2.38	No	GD

Missing data for n=4 total injuries

n: number of injuries (n=14 time-loss injuries; n=42 total injuries)

%: frequency of injuries reported in the study

Epidemiology of illness in netball players

During the 10 day tournament a total of 1440 player-days, were recorded for 192 players. A total of 11 illnesses in 11 players were reported calculating to an illness incidence of 7.64/1000 player-days (95%CI: 3.12-12.15) and period prevalence of 5.72%.

Main organ system, diagnosis and aetiology of illness

The incidence of illness by main organ system, diagnosis and aetiology of illness is shown in Table 6.

Table 6: Main organ system, diagnosis and aetiology of illness reported (% of all illness)

Main Organ System and Diagnosis				
Organ system	**Diagnosis**	**n (11)**	**%**	**Incidence per 1000 player-days (95%CI)**
All Illness		**11**	**100**	**7.64 (3.12 - 12.15)**
Respiratory	Upper respiratory tract illness	4	36.36	**
Non-Respiratory	All non-respiratory	7	63.64	4.86 (1.26 - 8.46)
Gastrointestinal	Gastroenteritis	2	18.18	**
Neural	Headache	1	9.09	**
Dermatological	Rash	1	9.09	**
Genitourinary	Dysmenorrhea	2	18.18	**
Other infections & parasitic disease	Other	1	9.09	**
Aetiology				
All infections		3	27.27	**
All non-infections		8	72.73	5.56 (1.71 - 9.41)

n: number of illness reported

%: frequency of illness reported in the study

I: Incidence per 1000 player-days

95%CI: 95% Confidence Intervals

**Number too small to calculate incidence accurately (incidence and 95%CI only reported for n≥5)

Most illnesses were non-respiratory system illnesses (63.64%). The most common specific diagnosis of illness was upper respiratory tract infection (n=4; 36.36%), followed by gastroenteritis and dysmenorrhea (n=2; 18.18% each). Non-infective illness (n=8; 72.73%) was more common compared to infective illness (n=3; 27.27%).

Time-loss illness (Severity)

The majority of illnesses did not cause time-loss from tournament play (n=10; 90.91%).

DISCUSSION

This is the first study to report on the incidence, period prevalence, types and severity of injuries and illness in elite netball players participating in an NWC Series. Our main findings are that the most common mechanism of injury involved contact (73.9%), primarily with an opposition player (91.2%), and that two-thirds (67%) of all injuries did not result in time-loss. Other findings include: 1) one in 5 players sustained an injury during the tournament; 2) the most frequently injured anatomical body region was the lower limb, specifically lateral ankle ligament sprains and this body region and clinical diagnosis also accounted for the most time-loss injuries (71% and 29% respectively); 3) centre players sustained more injuries than other player positions and centres and goal defenders also suffered most time-loss injuries; 4) injuries occurred in about 50% of matches; 5) upper respiratory tract infection was the most common specific illness (36% of all illnesses); and 6) 90% of all illnesses did not result in time-loss.

In our study of 192 elite female netball players, the incidence of contact injuries (73.91%; 40.48/1000 player-hours) was significantly higher than that of non-contact injuries (26.09%; 14.29/1000 player-hours). A previous study on South African sub-elite netball players competing in national university and provincial tournaments also reported that contact injuries are more prevalent (61%) [13]. In Australian community netball, collisions (28%) and awkward landings (27%) were the most frequent injury mechanisms [14]. Due to the physical nature of the game, it is fair to accept that contact injuries will be more common. Differences in the competitiveness of netball match-play and officiating may explain disparities in the incidence of contact between opposing players and subsequent injury. Additionally in the non-elite group, less body control may contribute to the risk of sustaining a contact injury. Unforeseen the more serious injuries (time-loss >7 days) were not caused by contact, but this cannot be generalized, as it portrays only 2 of the total injuries (5%).

A study on amateur non-elite players throughout one season reported 47% of injuries that resulted in time-loss of 1-4 weeks [16]. Our study on elite players during a short 10-day tournament showed that two-thirds of injuries did not result in time-loss. From the 14 time-loss injuries (33%), most were minor in nature (86%), and only 2 injuries (14%) caused time-loss of >7 days. Other contact sports in male athletes, including rugby and football tournaments of longer duration, reported more than 50% of injuries resulted in time-loss of ≥1 day [31, 32].

In our study across 10 consecutive days, one in 5 players sustained an injury with an injury incidence of 54.76/1000 player-hours. In other studies from a tournament setting, youth players (u/17 and u/19) during a six day Australian State netball championships had a higher incidence (89.4/1000 player-hours) [14] and sub-elite South African university players had a lower incidence (32.8/1000 player-hours) [13] compared to our study. In studies reporting on non-tournament settings and therefore not directly comparable to our findings, the injury incidence was lower in non-elite players from Australia (14.0/1000 player-hours) [15], Australian community netball clubs (13.8/1000 player-hours) [12] and a recent study of Australian inter-district and club teams (6.75/1000 player-hours) [6]. In a United Kingdom study on amateur players, the one season prevalence of injury was 54% and the overall (match and training) incidence of injury was 5.72/1000 player-hours [16]. It seems as though tournament play and inexperience (youth players) expose players to a higher risk of sustaining an injury. Contributing factors may be higher loading, competitiveness and the faster pace of the game in a tournament setting but further research is required.

Our study [ankle (24%), lower leg (11%) and knee involvement (9%)] concur with previous findings on injury surveillance in netball reporting the lower limb, specifically the ankle and knee, as the most frequent anatomical region involved across all levels of experience [8, 12, 13, 14, 16, 17, 21, 33, 34, 35, 36]. Lateral ankle ligament sprains (17.4%) and finger sprains (8.7%) were the most common clinical diagnoses. A further finding is that most time-loss injuries were sustained in the lower limb (71%), involving lateral ankle ligaments (29%). The lower limb involvement (frequency and severity) is expected as netball requires excessive jumping, landing and sudden changes in direction. These movements contain a high risk of contact with opposing or own team players, or a stagnant object e.g. the goal post that may cause lower limb injury. Additional factors include rapid acceleration and deceleration movements compounded by strict footwork rules that can also contribute to lower limb injuries. A usual conditioning program including muscle strengthening and proprioceptive training is essential to reduce lower limb injuries [37, 38, 39]. Additional important training implications may include training of the correct jumping and landing techniques during contact and non-contact situations [40]. Finger sprains are predictable due to complex ball handling and opposing players contesting for the ball. Finger sprains may be reduced by thoroughly warming up the hands before match-play and by including finger strengthening exercises during training sessions, but research is lacking.

In our study, centre players sustained more injuries (26%) than other player positions, followed by goalkeepers (22%) and goal defenders (17%). Also, centre players and goal defenders suffered the most time-loss injuries (29% each). Although we found no studies that related specifically to the number or mechanism of injuries per player position in netball matches, literature supports that centre players produce the highest physical load [4, 41], the highest mean total distance covered in match-play (5462.1 ± 169.4m), and the highest mean metres per minute ($90.0 \pm 2.5 m/min^{-1}$) [42]. In a study by Davidson and Trewartha [43] the goalkeepers had the second-highest distance covered (4283 ± 261m) after the centre players (7984 ± 767m). The fact that the centre players cover more distance may involve them in more contest for the ball, possibly increasing the likelihood of contact with other players and leading to subsequent injury. It is therefore not surprising that centre players sustained more injuries in our study.

There is no literature available reporting the number of injuries per match in netball. We reported an average number of 0.77 (0.66-0.87) injuries per match. In a field hockey women's tournament, an average number of injuries reported per match was 0.7 (0.5-1.0) [44] and an average of 1.5 (1.4-1.6) injuries per match was reported in female players of six international handball tournaments [45]. The Fédération International de Football Association (FIFA) reported the incidence of injuries per match in women football during the 1998–2012 period including the World Cups (1.9; 1.7 to 2.2), the Soccer Olympic Games (2.5; 2.2 to 2.8), the u19/u20 World Cups (2.6; 2.4; to 2.8) and the u17 World Cups (2.3; 2.0 to 2.6) [46]. Although handball is more comparable to netball, from these limited resources it seems as if the number of injuries for netball and field hockey is similar, and that handball and football have a much higher number of injuries per match. More research is required specifically related to the number of injuries occurring in netball matches.

In both the 2016 Summer Olympic Games in Rio de Janeiro and the 2014 Winter Olympic Games in Sochi, female athletes had a significantly higher risk of contracting an illness compared to male athletes [23]. We found no studies that related specifically to the incidence of illness in netball or other female teams participating in ball sports. The NWC is played only by females so we expected a high illness count taking into consideration that netball is a team sport and players are involved in close contact play and shared facilities all the time. We documented only 11 illnesses (7.64/1000 player-days). A study of the incidence of illness in athletes at the Rio de Janeiro Summer Olympic Games in 2016 showed an overall incidence of 5.7/1000 athlete-days [23], the FIFA Confederations Cup in 2009 reported an overall incidence of 16.9/1000 player-days [47], and the 2010 Super 14 Rugby tournament observed an incidence of 20.7/1000 player-days [48]. From this initial surveillance study, netball players competing at the NWC appear to be less exposed to illness, but further netball specific research is needed to reach definite conclusions.

Respiratory tract illness is widely reported as the most common organ system affected by illness [49, 50, 51, 52, 53]. The upper respiratory tract infection (URTI) [54] is the most common reason for non-injury-related presentations to sports medicine clinics, accounting for 35–65% of illness consultations [10, 11, 55, 56, 57, 58]. In Olympic [9, 10, 11, 59] and international competitions [57, 58], URTI interfered with training and the ability to compete in up to 10% of athletes. In our study, non-respiratory illness was more common at 64%, but URTI was the most common diagnosis (36%). In a prospective cohort study during the FIFA Confederations Cup in 2009, 37% of illnesses accounted for conditions of the ear, nose, and throat, and 20% of illnesses were as a result of other respiratory tract symptoms [47]. Preventative measures towards URTI remain important in all sporting codes.

In many studies, infection was the most common cause of illness [9, 48, 58]. Illness occurrences have led to the perception that respiratory tract infections are common in elite athletes [54], however, evidence to support this assertion is inconclusive and appears to be sport specific [55, 60]. Nonetheless, athletes presenting with an illness may experience a reduction in performance, negatively influencing many years of hard training. Although transient exercise-induced immune suppression can increase susceptibility to infection [61], not all episodes have an infective aetiology [62, 63, 64], and susceptibility may be influenced by other lifestyle and environmental factors [60, 61, 65]. In our study, non-infective illness was more common and accounted for 73% of illness.

Time-loss due to illness is a devastating consequence for the individual athlete and the team. In our study on a short 10-day tournament, illness did not result in time-loss. In other team sports where the event was of longer duration, the incidence of time-loss illnesses was 3.0/1000 player-days in elite football players [32] and 26.1% of illness resulted in a time-loss of ≥1 day in Super Rugby players [48]. In a study on Olympic athletes from 10 Great Britain Olympic sports codes during September 2009 - August 2012, the majority ($p<0.001$) of all illnesses (n=378) resulted in complete time-loss (n=270) compared to restricted activities (n=101) [66]. More data on time-loss due to illness are required in netball players.

In our study of 192 elite female netball players, the injury count (n=46, prevalence 20.3%) exceeded the illness count (n=11, prevalence 5.7%). This concurs with numbers from studies on the Olympic Games that include both males and females. In the Summer Olympic Games in London 2012 and Rio 2016, 1361 and 1101 injuries and 758 and 651 illnesses in 10568 and 11274 athletes respectively, were reported [11, 23]. In the Sochi 2014 Winter Olympic Games, 391 injuries and 249 illnesses were reported in 2780 athletes [9]. In studies on male-only participants, the 2009 FIFA Confederations Cup reported 56 injuries and 35 illnesses in 184 players [47] and the 2010 FIFA World Cup had 125 injuries and 99 illnesses in 736 players [32]. Netball specific studies comparing numbers of injuries and illness are not available.

Our study is the first to report on the epidemiology of injury and illness in elite netball players competing at the NWC2019. We report our results coherent with the agreed injury and illness research reporting methods published in the IOC consensus statement [28]. This includes consistency in the definitions and methods used, enabling the comparison of data across studies. A further strength is the accurate and reliable documentation of captured data (i.e. not self-reported) [36] and that there was

100% compliance by medical staff. Limitations include a low number of injuries and illness, with possible explanations including under reporting of data by the team medical staff and the fact that a netball team consists of only 7 players (12 players per squad), only 16 teams competed (pre-set number at the NWC), and the tournament lasted only 10 days. After the play-off phase of the tournament, 8 teams departed the tournament, i.e. on the last day of the tournament, only 8 teams were available for injury and illness surveillance. At the time of reporting the injury or illness, the attending medical officer estimated the total days lost to tournament play and did not report the exact days for return to play. Due to the low numbers of medical encounters, we could not analyze possible risk factors.

Research in this field must employ a similar methodology to allow for direct comparison between studies. We need more data on elite netball players to come to meaningful conclusions. Future studies should also look at risk factors to enable the application of preventative measures.

CONCLUSIONS

Our study is the first to report on the epidemiology of injury and illness during a netball world cup event. One in 5 players sustained an injury and as previously reported in other studies, the ankle is the most common anatomical region involved. The ankle is also responsible for 1/3 of the time-loss injuries. Centre players sustain most injuries and together with goal defenders suffer the most time-loss injuries. The mechanism of and time-loss due to injury mostly relates to contact, although 2/3 of all injuries reported did not result in time-loss. In contrast to other illness surveillance studies in sport, the respiratory system was not the most commonly affected, although URTI was the most common diagnosis. We need more injury and illness surveillance studies using the same methodology, to ensure useful development of preventative strategies and management of medical encounters in elite netball players.

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