2019

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10.1016/j.jsams.2019.05.013
Perera, N. K. P., Kountouris, A., Kemp, J. L., Joseph, C., & Finch, C. F. (2019). The incidence, prevalence, nature, severity and mechanisms of injury in elite female cricketers: A prospective cohort study. *Journal of Science and Medicine in Sport*, *22*(9), 1014-1020. Available here

Journal of Science and Medicine in Sport 22 (2019) 1014–1020

Contents lists available at ScienceDirect

Journal of Science and Medicine in Sport

journal homepage: www.elsevier.com/locate/jsams

Original research

# The incidence, prevalence, nature, severity and mechanisms of injury in elite female cricketers: A prospective cohort study

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ARTICLE INFO

*Article history:*
Received 12 December 2018
Received in revised form 16 May 2019
Accepted 20 May 2019
Available online 25 May 2019

*Keywords:*
Female
Athletic injuries
Injury rates
Cricket epidemiology
Bat-and-ball sports
Sports medicine

ABSTRACT

*Objectives:* Incidence, prevalence, nature, severity and mechanisms of injury in elite female cricketers over two seasons from March 2014 to March 2016, inclusive.
*Design:* Prospective cohort study.
*Methods:* Injury data collected via Cricket Australia's Athlete Management System on all elite female players over two seasons were analysed. Profiles of the nature, anatomical location and mechanism of injuries were presented according to dominant player position. Injury incidence rates were calculated based on match playing hours.
*Results:* There were 600 medical-attention injuries; with 77.7% players reporting ≥1 injury. There were 79.5% acute injuries compared to gradual onset injuries. Of the all medical-attention injuries, 20.2% led to time-loss; 34.7% were match-time-loss injuries. Match injury incidence was 424.7 injuries/10,000 h for all injuries and 79.3 injuries/10,000 h for time-loss injuries. Of all the injuries, 31.8% were muscle injuries and 16.0% joint sprains. Wrist and hand (19.8%), lumbar spine (16.5%) and knee (14.9%) injuries were the most common time-loss injuries. Six players sustained lumber spine bone stress injury that resulted in the most days missed due to injury (average 110.5 days/injury).
*Conclusions:* There is a need to focus on specific injuries in female cricket, including thigh, wrist/hand and knee injuries because of their frequency, and lumbar spine injuries because of their severity.


## Practical implications

- Most costly time-loss injury in women's cricket at the elite level was lumbar spine bone stress injury. There is a need for enhanced lumbar spine injury prevention strategies by correcting bowling technique, overall load management (e.g. Cricket Australia's Bowling Workload Guidelines) and back stability programmes to reduce injury risk.
- Time-loss from hand and wrist injuries are more common in female players than their male counterparts and should be a focus for prevention strategies such as skills training.
- The awareness of the increase injury risks in pace-bowlers and pace-bowling all-rounders may assist with workload management, match scheduling, training programs to minimise the injury risk.
- The most common injury mechanisms were insidious and workload management, increasing capacity (physical preparedness), tournament scheduling is important to mitigate the risk of these injuries.

## 1. Introduction

Injury prevention is an important focus for elite sporting organisations, because sports injuries result in missed game time[1] and may impair player performance.[2] Injury surveillance is the first step of prevention[3] and Cricket Australia has had a well-established

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https://doi.org/10.1016/j.jsams.2019.05.013

injury surveillance program for over 20-years for elite men's cricket.[4–7] Other cricket playing nations such as England,[8] South Africa[9] and New Zealand[10] have also published injury surveillance reports for men's cricket. Of the 1.4 million Australian cricket participants in the 2016–2017 season, more than 27% (n = 400,000) were female, and this was approximately 80,000 more female players than in the previous season.[11] Further, the 2017–2018 season saw female cricket participation increased to 30% of all players.[12] However, despite the recent growth of women's cricket at the national and international level, there are no published injury reports specific to female players.

To help prevent injuries in female cricket players, targeted injury surveillance is required. In men's cricket, injury surveillance over the past decade has identified that lumbar spine bone stress injuries and hamstring injuries have resulted in the most game-time missed due to injury.[6,7] Injury prevention strategies have therefore focussed on these specific injuries for men's cricket. For example, the annual injury incidence of hamstring strains changed from 3.1 in the 2006–2007 season, increasing up to 11.0 during the 2011–2012 season, and then gradually reduced to 7.7 in the 2015–2016 season.[13] Changing injury profiles reflect the changes to the match schedule with a gradual increase in the number of T20 games from 2006–2007 to 2011–2012 season, while the number of 50-over and First-class games stayed constant.[6] Through surveillance, the increasing workload was identified as a significant risk factor for injury[6] which then enabled successful workload management and team preparation. In addition, due to scheduling improvements, all domestic 50 over matches were played at the start of the season to minimise fluctuation of players workloads and this also contributed to a decline in annual hamstring strain incidence.[13] In addition to physiological differences between male and female athletes, female cricket players also have significantly different match loads due to minimal test matches compared to men which is likely to result in different risk factors for injury. However, it is unknown if female players have the same injury profiles as their male counterparts. This study aims to provide a detailed profile of medical attention injuries including match-time-loss injuries sustained by elite female cricketers over two seasons from March 2014 to March 2016, inclusive. Specifically, it aims to describe the incidence, nature, anatomical location and mechanisms of medical attention injuries sustained by Australian elite female players to provide a focus for injury prevention strategies.

## 2. Methods

The Athlete Management System (AMS) (Fair Play AMS 2016)[14] is a cricket -specific injury surveillance system with 100% coverage in elite cricket players (both male and female) in Australia. The AMS injury data were collected prospectively by the treating medical team member (doctor or physiotherapist) who coded them to the Orchard Sports Injury Classification System (OSCICS-10).[15] When each injury was logged on the AMS, the impact of the injury was assigned one of the following injury categories by the team medical staff:

1 available — not injured, and could play/train unrestricted,
2 modified — available to play but restricted from some match or training activities due to the injury (e.g. shoulder impingement — can bat/bowl/field in a match but limited to throwing over shorter distance than usual),
3 unavailable — not available to play a match due to injury (e.g. shoulder dislocation — unable to bat, field and/or bowl as required in a match).

It is important to note that injury data collected through the AMS do not capture the number of games missed due to each injury, as done in traditional injury surveillance programs.[16] However, it can automatically generate the number of days in a year for which the player was injured and unavailable, known as the player injury status. When each injury treatment consultation is entered onto the AMS by the medical team (either at a new or subsequent consultation), the player's injury status is updated (available, modified or unavailable). Typically, players transition between injury status categories as their injuries improve or deteriorate. Each injury could, therefore, be analysed for the number of days that the player was in each of the injury status categories (injury prevalence). While this study began before publication of the updated version of the international consensus definition in mid-2016,[17] the data were adjusted retrospectively to conform to the injury definition aligning with contemporary data collection methods across Cricket Australia, although it could make a direct comparison with historical studies of men's cricket data more challenging. The international consensus definition for medical attention injury[17] was used and included any injury that: required attention from medical staff and would potentially affect cricket training or playing (include both time-loss and non-time-loss injuries). Within the medical attention injuries, match-time-loss injuries were defined as an injury that resulted (or would result) in a player being unable to bat, bowl or wicket keep during a match if a match was scheduled.[17] The remaining medical attention injuries were considered as non-match-time-loss injuries

Injury data for female players competing in Australian national and international level tournaments over two consecutive cricket seasons (23 March 2014 to 22 March 2016) were extracted from the AMS by Cricket Australia to an Excel® (Microsoft Office Excel 2013) spreadsheet and then converted into SPSS® 22.0 (IBM SPSS Statistics 2015). Injury data that did not conform to the above definition and/or were not related to injuries during training for and playing cricket (e.g. injured playing football) were excluded.

To enable comparisons with previous cricket injury surveillance studies for male players, data were further divided into two 12-month cricket seasons.

Injury severity was defined as the number of days (from when the injury was sustained) that the player remained in the 'unavailable' category (i.e. injuries incurring time-loss) in accordance with the new international cricket injury definition.[17] Time-loss injuries (both training and match) were graded using an injury severity scale[18]:

1 minor (1–7 days),
2 moderate (8–28 days),
3 serious (29 days–6 months) and
4 long term (>6 months).

Players were classified as either an all-rounder, batter, pace-bowler, spin-bowler or wicketkeeper based on their dominant skill, identified on the AMS by Cricket Australia administrators. It should be noted that player skills could overlap (e.g. all players field and bat, but not all players would bowl, or wicket keep). All-rounders were defined by Cricket Australia administrators as players who were similarly proficient in more than one role (e.g. bowling and batting, or batting and wicket keeping). To enable comparisons, injuries were categorised by the player role and the activity at the time of the injury and mode of injury onset based on the international consensus definition.[17]

Descriptive statistics were used to describe the player demographic data, injury type, body region, nature and mechanism of the injuries reported. The injury incidence proportion (injury IP) for Season 1, Season 2 and the total 2-year period was calculated using the following formula[19]:

$$\text{Injury incidence proportion} = \frac{\text{number of injuries}}{\text{number of players}}$$

National and international matches played by elite female players over the 2-year surveillance period were used to estimate the exposure in terms of hours and overs (deliveries) played to calculate the match incidence.[17] Three different cricket formats currently exist and were used to calculate exposure. Twenty-twenty (T20) is the shortest version played over three hours, with 20 overs (120 deliveries) bowled by each team with a maximum limit of four overs (24 deliveries) per bowler. One-day (OD) cricket is played over seven hours, with 50 overs (300 deliveries) bowled by each team, with a maximum limit of ten overs (60 deliveries) per bowler. Test cricket, the multi-day format of the game, is played over four days in women's cricket (five days in men's cricket), with no limitations on bowler workloads. Therefore, each form of the game has differences in terms of exposure and the physical demands on players. Matches played in each season across the different game formats in a domestic and international tournament (Appendix A in Supplementary material) were used to calculate match injury incidence using the following formula in accordance with the international consensus for cricket injury definition:[20]

$$\text{Match injury incidence} = \frac{\text{number of injuries}}{\text{number of player hours}} x\, 10,000\, \text{hours}$$

The number of player hours (exposure) for an OD match was considered to be 43.3 player hours per team per match and 14.7 player hours per team per T20 match.[17]

All statistical analyses were performed using SPSS® 22.0 (IBM SPSS Statistics 2015).

Ethics approval was granted by the Federation University Australia Human Research Ethics Committee (Project number C16-002). To protect player privacy, all data cells correspond to counts of ≥5.[21] In cases where the injury categories could not be broadened in a meaningful way to ensure ≥5 cases, the value was replaced by an asterisk (*) in the presentation of results.

## 3. Results

The mean age of the 121 included players was 24.2 ± 4.5 years. Season 1 included 89 players; 96 players were included in Season 2, and 64 players were involved in both seasons. Of the 121 players, 113 players sustained 600 medical-attention injuries, and 94 out of the 113 (77.7%) players sustained >1 injury during the 2-year study period. Among the medical-attention injuries, there was a higher incidence of new injuries (73.2%) compared to recurrent injuries (26.8%), and acute injuries (79.5%) compared to gradual onset injuries (20.5%). Of the all medical-attention injuries, 121 (20.2%) were time-loss injuries, and 42 of these injuries to match-time-loss. Total match injury incidence was 424.7 injuries per 10,000 player hours (Table 1).

When the injuries were grouped into player role and activity at the time of the injury,[17] the majority of the wrist and hand injuries (13.7%) and shoulder injuries (9.1%) were sustained during fielding. Similarly, muscle injuries (9.4%) and joint sprains (7.4%) were sustained during fielding. Further, catching (10.7%) and throwing (10.7%) were the most common injury mechanisms when players are fielding where sudden-onset non-contact injury (24.9%) and impact/traumatic injury (17.1) were the most common mode of injury onset during fielding. Of the injuries sustained during batting, 4.8% were thigh injuries, and 9.7% were injuries to muscle. There were 6.3% muscle injuries during bowling with bowling delivery being the common injury mechanism (16.5%). Further, 16.5% of the injuries sustained during bowling were sudden-onset non-contact injury onset (Table 2). When the players were grouped

**Table 1**
Match injury incidence per 10,000 player hours in Australian elite female cricketers in the 2014–2015 and 2015–2016 seasons.

| | Twenty-twenty (T20) match | | | | One-day (OD) match | | | | Multi-day match | | | | Total | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No of matches | Total exposure | Numberof injuries | Match injury incidence for 10,000 player hours | Number of matches | Total exposure | Number of injuries | Match injury incidence for 10,000 player hours | Number of matches | Total exposure | Number of injuries | Match injury incidence for 10,000 player hours | Number of matches | Total exposure | Number of injuries | Match injury incidence for 10,000 player hours |
| Season 1 | 59 | 865.4 | 41 | 473.8 | 32 | 1386.7 | 37 | 266.8 | 1 | 78 | 2 | 256.4 | 92 | 2330.1 | 80 | 343.3 |
| Season 2 | 75 | 1100.0 | 77 | 700.0 | 35 | 1516.7 | 62 | 408.8 | 3 | 351 | 6 | 170.9 | 113 | 2967.7 | 145 | 488.6 |
| Time-loss | 134 | 1965.4 | 24 | 122.1 | 67 | 2903.3 | 14 | 48.2 | 4 | 429 | 4 | 93.2 | 205 | 5297.7 | 42 | 79.3 |
| Non-time-loss | 134 | 1965.4 | 94 | 478.3 | 67 | 2903.3 | 85 | 292.8 | 4 | 429 | 4 | 93.2 | 205 | 5297.7 | 183 | 345.4 |
| Total[a] | 134 | 1965.4 | 118 | 600.4 | 67 | 2903.3 | 99 | 341.0 | 4 | 429 | 8 | 186.5 | 205 | 5297.7 | 225 | 424.7 |

Number of player hours per team per match[11,15]: T20 = 14.7 h, OD = 43.3 h, multiday = 39 h per day.
[a] Medical-attention injuries.

**Table 2**
Anatomical location, nature, mechanism and mode of onset of all injuries categorised by player role and activity at the time of injury.

| | Player role and activity at the time of injury (%) | | | | Total (%) |
|---|---|---|---|---|---|
| | Batting | Bowling | Fielding | Wicketkeeping | |
| Anatomical location of the injury (n = 351) | | | | | |
| Wrist and hand | 2.8 | 1.7 | 13.7 | 2.0 | 20.2 |
| Shoulder | 2.0 | * | 9.1 | * | 12.5 |
| Thigh | 4.8 | * | 4.0 | 1.4 | 11.4 |
| Knee | 2.3 | 2.3 | 3.7 | * | 9.1 |
| Lumbar spine | 2.8 | 3.1 | 2.0 | – | 8.0 |
| Ankle | 1.7 | 2.0 | 2.8 | * | 6.8 |
| Lower leg | 2.6 | 1.4 | 2.6 | – | 6.6 |
| Foot | 1.4 | 2.3 | – | * | 4.0 |
| Head | * | – | 1.4 | * | 3.1 |
| Trunk and abdominal | * | 2.3 | * | – | 3.1 |
| Pelvis/buttock | 1.4 | – | 1.4 | – | 2.8 |
| Thoracic spine | * | * | * | – | 2.6 |
| Elbow | * | – | 1.4 | – | 2.6 |
| Hip and groin | * | * | * | * | 2.6 |
| Neck | * | * | * | * | 2.3 |
| Forearm | * | – | * | – | * |
| Upper arm | * | * | – | – | * |
| Unspecified | * | – | – | * | * |
| Chest | – | – | * | – | * |
| Nature of the injury (n = 351) | | | | | |
| Muscle injury | 9.7 | 6.3 | 9.4 | 1.4 | 26.8 |
| Joint sprains | 5.4 | 3.4 | 7.4 | 1.4 | 17.7 |
| Bruising/haematoma | 3.1 | 2.0 | 7.1 | * | 13.4 |
| Synovitis, impingement, bursitis | 2.8 | 2.8 | 5.4 | * | 11.4 |
| Tendon injury | 1.4 | 1.4 | 3.7 | * | 6.8 |
| Fracture | * | – | 3.4 | – | 4.6 |
| Otherwise unspecified | * | * | 2.0 | * | 4.5 |
| Joint dislocations | – | * | 2.3 | * | 2.8 |
| Laceration/abrasion | * | * | 2.0 | * | 2.8 |
| Nerve injury | * | * | 1.4 | * | 2.8 |
| Cartilage injury | * | * | * | * | 2.3 |
| Stress fracture | * | * | – | * | 1.4 |
| Chronic instability | * | – | * | – | * |
| Other stress/overuse injury | * | * | * | – | * |
| Arthritis | * | – | – | – | * |
| Injury mechanism (n = 346) | | | | | |
| Bowling delivery | – | 16.5 | – | – | 16.5 |
| Insidious | 8.1 | 2.9 | 1.7 | 2.0 | 14.7 |
| Diving | 4.0 | – | 9.2 | * | 13.6 |
| Running | 6.6 | * | 5.8 | * | 13.3 |
| Catching | – | – | 10.7 | 2.3 | 13.0 |
| Throwing | * | – | 10.7 | – | 11.0 |
| Ball collision | 5.8 | – | 3.8 | * | 10.1 |
| Fall/slip/lunge/change direction | 2.0 | – | 4.0 | * | 6.9 |
| Player collision | * | * | * | * | * |
| Mode of onset (n = 346) | | | | | |
| Sudden-onset non-contact injury | 6.4 | 15.9 | 24.9 | 2.6 | 49.7 |
| Impact/traumatic injury | 12.1 | – | 17.1 | 2.0 | 31.2 |
| Insidious (gradual onset and no identifiable mode of onset) | 5.8 | 3.5 | * | 1.7 | 12.1 |
| Gradual onset associated with bowling/running/throwing/batting practice/weight training | 3.2 | * | 2.9 | * | 6.9 |

*Injury count is <5.
Terminology used for anatomical locations and nature of injuries are based on the OSICS-10.[15]
Analyses were performed on complete data, discrepancies between total sample size (n = 600 injuries) and variable count are due to missing data.

into their dominant skill, all-rounders and pace-bowlers sustained 38.5% and 28.9% of all medical-attention injuries respectively. More specifically, pace-bowlers and pace-bowling all-rounders sustained more injuries than other players in the squad accounting for 47.8% of all injuries (Appendix A in Supplementary material).

Of all medical-attention injuries, thigh (n = 84, 14.0%), wrist and hand (n = 77, 12.8%) and knee (n = 68, 11.3%) were the most frequently injured regions. There were 191 (31.8%) muscle injuries and 35.7% (n = 30) of all thigh injuries were to the hamstring.

There were 121 (20.2%) time-loss injuries (94 new and 27 recurrent) with a total of 3638 days (average 60 days, SD ± 47.38 per injury) unavailable over the 2-years of the study. The incidence of time-loss injuries during matches was 79.3 injuries/10,000 h (Table 1). Injuries to the wrist and hand (19.8%), lumbar spine (16.5%) and knee (14.9%) were the most common time-loss injuries. Six players (including five pace-bowlers) sustained lumbar spine bone stress injuries that resulted in the most days missed of any injury (average 110.5 days per injury) (Table 3).

## 4. Discussion

This prospective cohort study investigate the incidence, nature and mechanisms of injuries sustained by Australian elite female cricketers. Match injury incidence (time-loss) of 79.3 injuries/10,000 h was higher in elite female cricketers compared to elite male cricketers (range 27.9–47.8 injuries/10,000 h) over

**Table 3**
The anatomical location and nature of most common medical-attention, time-loss injuries and match-time-loss injuries and days unavailable to play.

| | All injuries n = 600 (%) | Time-loss injuries n = 121 (%) | Match-time-loss injuries n = 61 (%) | Total days unavailable to play** (average days per injury)s |
|---|---|---|---|---|
| Lumbar spine (L) | 10.5 | 16.5 | 16.4 | 898 (44.9) |
| Lumber spine bone stress injury (LS) | | 4.9 | * | 663 (110.5) |
| Knee injuries (K) | 11.3 | 14.9 | 11.5 | 759 (42.2) |
| Synovitis, impingement, bursitis (KG) | | 4.9 | * | 93 (15.5) |
| Cartilage injury (KC) | | 4.1 | * | 262 (52.4) |
| Wrist and hand (W) | 12.8 | 19.8 | 21.3 | 531 (22.1) |
| Wrist and hand fractures (WF) | | 9.9 | * | 416 (34.7) |
| Thigh injury (T) | 14.0 | 15.7 | 11.5 | 368 (19.4) |
| Hamstring injury (TM) | | 14.0 | 11.5 | 307 (18.1) |
| Shoulder injuries (S) | 11.0 | 5.8 | 8.2 | (51.7) |
| Ankle (A) | 5.8 | 6.6 | 8.2 | 154 (19.3) |

*Injury count is <5.
**General time-loss days.
Terminology used for anatomical locations and nature of injuries are based on the OSICS-10.[15]

10-years.[6] The difference could be explained by the injury definitions used, with previous studies in men's cricket using a time-loss definition that strictly included only injuries resulting in matches missed due to injury,[17] consequently under-reporting the total number of injuries thus lower injury rates. In comparison, the current study counted the number of days that the player would have been unavailable to play, irrespective of whether matches were scheduled, and thus, capturing the duration that players were incapacitated due to injury rather than simply matches missed (e.g. off-season injuries).

Most injuries (73.2%) in this study were new injuries, which is similar to findings reported in men's cricket (80–92% new injuries).[7] Additionally, 77.7% of players sustained multiple injuries; 26.8% of all medical-attention injuries and 22.3% of all time-loss injuries were recurrent, which is an important finding because the previous injury is a risk factor for re-injury.[22] The majority (57.1%) of all injuries (medical attention and time-loss) occurred in pace-bowlers or pace-bowling all-rounders, as is similar to injury data in male cricketers.[7] The unnatural and repetitive action of pace-bowling are likely to predispose pace-bowlers to greater injury risk in comparison to other player roles. Additionally, in elite men's cricket high sustained bowling workloads and workload spikes have been identified as risk factors for cricket pace-bowlers.[5] It is likely that elite female pace-bowlers may be exposed to the same risks as their male counterparts. However, females are not likely to experience the same workload spikes and possibly the very high sustained bowling loads as men because they would not have the same match scheduling. Further, compared to the male players, female cricketers play very few test matches. It is, therefore, difficult to conclude that the same workload factors drive injury risk in female pace-bowlers but does highlight that pace-bowling involves repetitive high impact forces that predispose all players to injury.[23] Another possible explanation could be that with more training/preparation periods than matches, female players may not reach 'match' intensity at training, and possibly sustain injuries as they transition from the training environment to competitive matches. Future research should focus on the impact that increasing match scheduling and increasing workloads could have on injuries in women's cricket.

The relatively large number and ranking of thigh injuries may be mechanistically explained by bursts of running, catching, diving and bowling. For example, sprinting,[24] where sudden high-speed acceleration or deceleration (such as running between wickets or chasing a ball during fielding) may cause a hamstring injury. The bowling delivery stride, being one of the most common mechanisms, highlights the risk associated with the bowling action[25] and might also explain the knee injuries reported in pace-bowlers and pace-bowling all-rounders.

The wrist and hand region was associated with the most common time-loss injury averaging 22 days unavailable to play cricket. This appears to be overrepresented in women compared to men.[6,7] Lacrosse is another sport where female players have high rates of wrist and hand fractures,[26] with both sports involving the risk of a hard ball striking the hand and fingers. In cricket, players are at risk of finger and hand injuries because fielders must catch or stop a fast-moving hard ball without gloves (except the wicketkeeper). Finger injuries also occur by being struck by the ball while batting, irrespective of protective gloves. Although the size and weight of balls used in women's cricket is smaller than balls used in men's cricket,[27] and the peak delivery speeds up to 120 km/h,[28] there is significant potential for the balls to cause injury. Despite the smaller balls and slower bowling speeds, compared to men, these injuries still occur. It is possible that due to the infancy of professional women's cricket, some players may have catching and fielding techniques that predispose them to hand and finger injuries.

Lumbar spine injuries were the second most common time-loss injury. Importantly, there were six lumbar spine bone stress injuries (including stress fractures) recorded, predominantly on pace-bowlers resulting in the most game days missed per injury (average 110.5 days unavailable per injury). This study demonstrates that elite female cricketers develop lumbar bone stress injuries, similar to their male counterparts.[7] In elite men's cricket, this injury has attracted much research, because the injuries require long recovery periods.[23] Workload,[4,5] and technique factors such as excessive shoulder counter-rotation and trunk lateral flexion associated with side-on, front-on or mixed bowling actions[25]; and the associated repetitive lumbar loading[23] have been associated with increased risk of lumbar bone stress injuries in male players. These factors were not considered in the current study but could also be an important factor for female players. Although female cricketers currently do not experience same acute workloads as males due to differences in match scheduling, it is possible that the increased professionalism of female players in recent years may have resulted in relatively higher training and match bowling loads. These increased workloads might predispose players to lumbar bone stress injuries. Future research should focus on female player's bowling technique and workload to provide information relating to injury risk factors, aetiology and mechanisms of injuries.

Epidemiological data collected through injury surveillance provide a strong basis for the development of appropriately targeted and evidence-based injury prevention programs, as well as providing a baseline against which to evaluate the success of such programs.[3] In particular, the number of lumbar spine bone stress injuries reported suggests that similar to men, increasing workloads may increase the risk of injury in female cricketers, subsequently highlighting the need for evidence-based female specific bowling guidelines. Further, bowling kinematics and kinetics need to be investigated in female players. For example, females have a greater lumbar lordosis curvature extends across three vertebrae compared to lordosis curves across two vertebrae's in males and females have a caudally located lordotic peak, and greater cranial peak height.[29] Therefore, given the differences in structure, it is uncertain whether the same risk factors that predispose male players to injury also affect female players, but in the absence of any other evidence, these should be considered.

Bone stress injuries are thought to represent the inability of the skeleton to withstand repetitive bouts of mechanical loading causing structural fatigue. Previous studies indicate that female athletes are more vulnerable to bone stress injuries than their male counterparts, and approximately 30% of female collegiate athletes were at moderate (25.5%) or high (3.8%) risk for bone stress injury.[30] The Relative Energy Deficiency in Sport (RED-S),[31] may explain the larger than expected lumbar bone stress injuries and why some of these injuries occurred in batters. The RED-S considers the relationship between energy availability, menstrual function and changes to the bone mineral density in response to training loads, the intensity of training, stress levels and nutrition status.[31] However, this needs confirming in future studies.

Several limitations in this study should be addressed. We did not record games missed, and therefore, the measure of injury prevalence cannot be accurately compared to previous studies in men's cricket that used games missed to define time-loss. Match injury incidence was calculated based on match fixtures to enable comparison with previous men's cricket injury epidemiology research. The exposure hours were estimated based on averages for the number of matches played, rather than collecting individual match exposure. However, exposure in terms of hours of play was calculated in accordance with the internationally recognised cricket injury definition.[17,20] Injury types were not defined using uniform diagnostic criteria and therefore the coding of the injury diagnosis might not be consistent between the medical professionals inputting the data into AMS medical notes, limiting the accuracy of the data. The data was collected from 2014 to 2016. As the women's game continued to grow, workloads of female cricketers increased from 2017 to 2018 and increasing workloads likely to have influence the current injury profiles. However, as women's cricket develops, appropriate physical preparedness, workload management and effective monitoring may mitigate the injury risks.

## 5. Conclusion

This prospective cohort study investigated injuries sustained by Australian elite female cricket players. There is a need to focus on specific injuries in female cricket, including thigh, wrist/hand and knee injuries because of their frequency, and lumbar spine injuries because of their severity. Importantly, this study demonstrated that elite female cricketers develop lumbar spondylolysis, like their male counterparts. The findings of this study may provide a basis for injury prevention programs in elite women's cricket.

## Financial support

NKPP was supported by a Federation University Australia Postgraduate Scholarship and Centre for Sport, Exercise and Osteoarthritis Research Versus Arthritis - Sports Grant (HFR02510).

## Contributorship

All authors contributed to all items in the ICMJE contributorship guidelines.

## Acknowledgements

The authors wish to acknowledge Cricket Australia for their support.

## Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.jsams.2019.05.013.

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