Original research

Caught on camera: a video assessment of suspected concussion and other injury events in women's rugby union

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ABSTRACT

Objectives: The objective of this study was to identify and report the incidence and mechanisms of suspected injury and concussion in women's rugby union.
Design: A cross-sectional video analysis study.
Methods: Using video analysis of non-professional, single-angle footage, cases of suspected injury and concussion were identified and reported, based on content validation and consensus by eight rugby-specific researchers, therapists, and sport medicine physicians.
Results: There were 225 suspected injuries recorded in 48 games [Suspected injury rate (IR) = 117.5/1000 h (95 % CI;102.6–133.9) or 4.7 suspected injuries per match]. The on-field medical attention IR was 95.0/1000 h (95 % CI;81.7–109.9: 3.8 per game). Suspected concussions accounted for 26 % of injuries (30.8/1000 h: 95 % CI;23.5–39.7: 1.2 per game). The attacking team sustained 64 % of suspected injuries. Permanent removal from play was observed for 29 % of suspected injuries. The most common suspected injury locations were head/neck (28.4 %) and lower extremity (27.6 %). The tackle accounted for 67.1 % of all suspected injuries, with a propensity of 11.2/1000 tackle events (95 % CI;9.5–13.2) or 3.1 tackle-related injuries/game. Of tackle-related injuries, 63.6 % were to the ball carrier while 52.2 % of tackle-related concussions were to the ball carrier.
Conclusion: This study adds to the growing body of literature examining women's rugby. The rate of suspected injury is high compared with other studies. It is acknowledged that these are suspected injuries not supported by prospective injury surveillance. The high proportion of suspected injuries that are tackle-related warrants specific attention to identify tackle characteristics associated with injury and concussion.

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Practical implications

- This study has presented a cost-effective approach using validated criteria to supplement prospectively collected injury surveillance data
- This study has demonstrated the need for further education and training of all pitch-side stakeholders to assist in the identification and appropriate removal of players with suspected concussion

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- This study has demonstrated the high risk associated with the tackle event in women's rugby union and the need for a focus on tackle training to minimise the risk of injury and concussion

1. Introduction

Rugby Union (rugby) is a popular collision sport, played by nearly 3 million women globally.[1] Despite growing participation rates, rugby is considered to have a relatively high risk of injury (Women: 19.6/1000 h,[2] Men: 46.8/1000 h[3]) compared with other collision team sports. However, evidence surrounding injury risk is sparse in the women's game. In a 2019 systematic review, only four papers on women's 15-a-side rugby were retrieved.[2] Comparatively, fifteen studies in the professional men's game were identified in a 2013 review[4] and a further nineteen in a 2021 update.[5] Furthermore, a recent analysis in the women's game identified substantial differences in head-impact mechanisms between the men's and women's game, concluding that the findings of their study did not support the generalization of male-derived injury prevention data to women.[6] Strengthening the evidence base of women's injury epidemiology and a greater understanding of injury mechanisms and injury context is urgently needed to inform sex-specific injury prevention strategies.

Prospective cohort studies are the gold-standard in longitudinal observation of injury in sport. However, such studies are time and resource intensive. Given the clear need for more research examining the rates and mechanisms of injury in women's rugby, other methods are required. Video analysis has been widely used in men's rugby to study specific characteristics of high-risk game events, such as the tackle.[7–9] In other sports, video analysis has been used to describe specific injury incidents[10] as well as examine their mechanisms.[11] Although using video-analysis to estimate incidence rates is not commonplace, especially in the absence of supporting prospectively collected injury data, the need for further women's injury data is apparent and could benefit from the use of such methods to inform injury prevention strategies. Therefore, the aim of this study was to examine the rates of suspected injury and suspected concussion, as well as to examine the location, mechanisms, on-field management, and propensity of these injuries in the women's game using video-based analysis of match events.

2. Methods

This was a video analysis study including 48 matches over three seasons (2017, 2018, 2019) of women's varsity rugby in Western Canada. Players typically range from 18 to 25 years of age, however there may be players outside this range. Given the retrospective, anonymous nature of the match footage, more accurate demographic details could not be obtained. Video analysis was from video captured by teams for the purposes of regular team performance and game review. For most games, a single camera from an elevated position close to centreline was used. Permission to use this video for the purposes of anonymous video-analysis was obtained from the league director and videos were obtained from the Athletic Director of one team. This study received ethical approval from the Conjoint Health Research Ethics Board at the University of Calgary (Ref: REB20-1443).

During initial coding of match events (e.g., tackles, scrums, rucks, mauls), any instances of a player staying down or demonstrating physical discomfort (e.g., limping, slow to return to feet, clutching at area in pain, seeking medical attention) were coded for further investigation. This initial coding was undertaken by six trained student coders with reliability between these coders previously reported as "almost perfect" (Kappa scores: 0.88–0.96).[12] After the initial coding, one coder (SWW), individually exported each clip to show the onset of suspected injury (inciting event/first appearance of pain), as well as the resolution of the suspected injury (removed from field/return to play).

As no prospectively collected injury data was available for these videos, only suspected injury and suspected concussions could be considered in this study, the methods for which are outlined below. Six highly trained and experienced international sports medicine physicians (n = 3; median experience: 26 years; range: 6–35) and athletic therapists/physiotherapists (ATs/PTs) (n = 3; median experience: 15 years; range 10–17) were recruited to act as injury coders to identify suspected injuries and concussions. Coders were chosen based on their experiences within the game in elite and non-elite settings. There were three key methodological stages in this study outlined below which include content validation of injury and concussion criteria, inter-rater reliability for coders, and coding of remaining clips.

Initially, each coder completed content validation of injury and concussion criteria. Each coder was asked to report if they considered each criterion (listed below) to be valid for suspected injury/concussion using video alone and subsequently reported any perceived strengths and weaknesses, using an open response field on a questionnaire. Criteria were included if 50 % of the clinicians believed the criteria were valid to recognise suspected injury/concussion. Fifty percent was chosen to be as inclusive as possible of criteria at this stage of the process, prior to any clips being analysed. The criteria included for suspected injury were adapted for a rugby context[10] (Table S1): "a situation in which the match was interrupted by the referee", "a player lay on the pitch for more than 15 seconds", "the player appeared to be in pain" and "the player received medical treatment". In line with feedback from the "strengths and weaknesses" listed by the clinicians the time a player remained down was changed to 10 s as the clinicians agreed it was not within the rugby culture to remain down unless injured. All criteria achieved at least 50 % agreement as valid measures. The largest weakness was described as difficulty in evaluation from video footage alone. To ensure that "pain" was deemed as related to injury and not related to game-related fatigue, coders were instructed to code "pain" when there was a clear inciting event which may have been associated with this apparent physical pain. To identify a suspected concussion, four tools were content validated for the purposes of this study: 1. The on-field indications for permanent removal from World Rugby's Head Injury Assessment protocol[13]; 2. Observable signs from the concussion recognition tool 5[14]; 3. Clear indicators of a concussion from World Rugby's concussion guidance document[15] and: 4. Criteria from the 2019 consensus definitions of video signs of concussion in professional sport.[16] These four tools were chosen given their use as aides for the recognition of concussion by pitchside clinicians. The key challenge outlined by the study clinicians included difficulty in identifying some criteria without in-person assessment, for example, blank or vacant stare. Furthermore, it may be difficult to assess criteria when incidents occurred in field positions distant from the camera. Despite these challenges, using the same content validation process as described for injury, a list of 15 criteria from across the four tools gained support for inclusion (Table S2).

Following the selection of criteria, 63 clips randomly selected clips were circulated with eight coders (6 medically trained as described, plus two non-medically trained study personnel) to establish inter-rater reliability. If a video clip was recorded as a suspected injury/concussion by at least 50 % of medically trained coders, that was considered a suspected injury or concussion. Any clip which achieved this level of agreement was considered the gold standard response for that injury event, to allow for comparison between each coder and the consensus from the group. A minimum threshold of 70 % agreement between each rater and the gold standard score was required. Inter-rater agreement between all coders, physicians, athletic therapists/physiotherapists, and non-medically trained coders can be seen in Table S1 (injury criteria) and Table S2 (concussion criteria). All coders (medically trained and non-medically trained) were briefed on the study methodology and evaluation of criteria in the same way to maintain consistency across coders. As three of the raters (one doctor, one AT and one non-medical coder) were familiar with the clips due to their involvement with a team in the footage, they were prevented from coding injuries in which they knew the outcome. All other coders were randomly assigned clips.

Following inter-rater reliability, groups of three coders were formed (one physician, one athletic therapist/physiotherapist, and one non-medical coder) to code the remaining 175 clips. For the injury/concussion to be included in the study, at least two of the three coders must have reported it as being a suspected injury/concussion. As no true medical diagnosis could be captured, coders were asked to apply "recognise and remove" criteria for suspected concussion, which are appropriate for this level of rugby. Several other injury details were recorded including the event causing injury, the injured player (attacker/defender), player removal from play and foul play.

Inter-rater reliability was assessed using the percentage agreement between raters with a minimum threshold of 70 % agreement required. Descriptive characteristics of the injuries were reported as a proportion of all injuries. Match exposure was calculated as the number of games (n = 48) multiplied by the number of players exposed per fixture (n = 30) multiplied by 1.33 (match length in hours).[17] Suspected injury and concussion incidence rates were reported based on Poisson regression [# injuries/1000 match hours, 95 % confidence intervals (CIs)]. Rates were reported for all injury (any suspected injury which met one of the four criteria- includes medical attention and concussions), medical attention injury (only those which meet the medical attention criteria- includes concussions), and concussion (only those which met one of the concussion criteria). Medical attention was reported separately given its widespread use in injury epidemiology literature in line with the IOC consensus statement for recording of injury and illness data.[18] Using the count of tackles reported previously from the same dataset,[12] propensity of injury/concussion per 1000 tackles/rucks was reported, with 95 % CIs. All analysis, including calculation of rates, were undertaken in STATA (StataCorp, 2019, Stata Statistical Software: Release 16. College Station, TX: StataCorp LLC).

3. Results

All data reported here are based on video analysis suspected injury and suspected concussion definitions and are not supported by prospectively collected injury surveillance data. Percentage agreement between each of the coding groups for injury is reported in Table S1. "Medical attention" was the injury criterion with the highest level of agreement between raters. A high percentage of agreement for concussion criteria are seen in Table S2, however this is due to the low number of cases in which positive criteria outcome were evident.

Of the 238 potential injury events, 225 (95 %) were deemed to meet the criteria for suspected injury in 1915 h of match exposure. The median number of criteria met for cases classified as suspected injury was 3 (/4: interquartile range (IQR): 2–3) of the 225 coded injuries, 81 % required medical attention. Fifty-nine suspected concussions were recorded [26 % of all injury: median criteria: 2 (/15) (IQR: 2–3)]. Of the 225 injuries, 64 % occurred to the attacker, while 35 % occurred to the defender (1 % not applicable as no player in possession). The player was permanently removed in 29 % of the suspected injuries, with 64 % remaining on the pitch. In 4 % of cases, it was unclear whether the player left the field of play (e.g. the injury occurred at the end of the game). For suspected concussions, 39 % of players left the field, 54 % remained on the pitch, and 7 % were unknown. Only 3 % of injuries were sanctioned as a penalty by the on-pitch referee. Of the suspected concussions, 10 % (6/59) received no on-pitch medical attention, while 19 % of suspected injuries (43/225) did not receive on-field medical attention.

The rate of all suspected injuries was 117.5/1000 h (95 % CIs: 102.6–133.9). For comparison with other medical attention definition data, the rate of medical attention injury alone was 95.0/1000 h (95%CIs: 81.7–109.9: Table 1). The rate of suspected concussion was 30.8/1000 h (95 % CIs: 23.5–39.7: Table 1). On average, there were five suspected injuries and one suspected concussion identified per game.

The tackle event (as defined by the consensus for video analysis in rugby union[19] as "An event where one or more tacklers (player or players making the tackle) attempted to stop or impede the ball-carrier (player carrying the ball) whether or not the ball-carrier was

brought to ground") was responsible for the highest proportion of all suspected injuries (67 %), medical attention injuries (68 %) and concussions (78 %: Fig. S1). Of the tackle-related suspected injuries, 64 % were to the ball carrier and 36 % to the tackler. For tackle-related suspected concussions, 52 % were to the ball carrier and 48 % were to the tackler. Of the tackle-related suspected concussion events, 39 % were from player-to-player contact, 7 % were from head-to-ground contacts (during close-quarters action), 17 % from head-to-ground contacts during an uncontrolled fall, 11 % involved both head-to-ground and head-to-head contact, and 26 % of cases were unclear. Tackling demonstrated the highest propensity for injury [11.2 injuries/1000 tackles (95 % CIs: 9.5–13.2)], followed by the scrum [9.2 injuries/1000 tackles (95 % CIs: 4.6–16.4): Table 2]. However, given the frequency with which the tackle occurs compared with the scrum, rates of suspected injury per game (by different event types) are seen to be dramatically higher for the tackle compared with the scrum. Head/neck and lower limb were the two most frequent injury locations (Fig. 1).

4. Discussion

This study aimed to examine the rates of suspected injury and concussion and describe the match events leading to these injuries in a women's cohort of Rugby Union players. The rates of injury and concussion were high across all definitions; however, it must be recognised, these were suspected injuries only and are not supported by prospectively collected injury data. Only 29 % of suspected injuries required the player to be immediately removed from the game. The events causing injury were consistent with previous literature. Again, caveated by the fact that no in-person on-field assessment could occur in this study, it is noteworthy that only 39 % of players with a suspected concussion left the field because of their suspected head injury. Although unique in its approach to assessment of injury rates in the game, this study provides useful information for all stakeholders in the women's game to support sex-specific discussions regarding player welfare and injury prevention strategies.

Video analysis has previously been used in rugby and other sports to assess injury mechanisms and support injury prevention strategies.[8,9,11] Given the pressing need for more women's rugby data to contribute to such conversations, this study has used video analysis methods to inform the risk of suspected injury as well as the mechanisms and management of injuries. In an attempt to make this process as valid and reliable as possible, four injury criteria from previous work in soccer[10] and 15 concussion criteria[13–16] were chosen after content validity by a group of six experienced sports medicine doctors and physiotherapists/athletic therapists, all with an extensive knowledge of rugby. Future studies should consider comparison with a gold standard of medical diagnosis. However, given the high level of agreement between coders, medical attention alone could be used for future studies. Based on the selected criteria, it is clear that the threshold for a suspected concussion in this study may be considered low given that some criteria, for example "grabbing/clutching of head" and "slow to return to feet after direct or indirect head contact", could occur for other reasons outside of concussion and are considered non-specific.[16] In contrast, as per the eight criteria listed in the international consensus definitions of video signs of concussion in professional sports,[16] it is clear that while the diagnostic threshold for concussion is higher and more accurate, the ability to see these criteria using non-professional video footage with only one angle to view is

Table 1
Suspected injury and concussion rates.

Injury type	Rate/1000 h (95 % CIs[a])	Rate/match [(95 % CIs[a]); (Range)]
All injury	117.5 (102.6–133.9)	4.7 [(4.1–5.3); (0–11)]
Medical attention injuries	95.0 (81.7–109.9)	3.8 [(3.3–4.4); (0–9)]
Concussion only	30.8 (23.5–39.7)	1.2 [(0.9–1.6); (0–4)]

[a] CIs: confidence intervals.

Table 2
Suspected injury and concussion propensity.

All suspected injury			
Match event	Injury/1000 events (95 % CIs[a])	Events per injury (95 % CIs[a])	Injuries per game
Tackle	11.2/1000 tackles (9.5–13.2)	1 injury every 89 tackles	3.1 tackle-related injuries/game
Ruck	3.3/1000 rucks (2.3–4.7)	1 injury every 303 rucks	0.7 ruck-related injuries/game
Scrum	9.2/1000 scrums (4.6–16.4)	1 injury every 109 scrums	0.2 scrum-related injuries/game
Concussion only			
Tackle	3.4/1000 tackles (2.5–4.6)	1 concussion every 294 tackles	1.0 tackle-related concussions/game
Ruck	0.7/1000 rucks (0.3–1.5)	1 concussion every 1428 rucks	1 ruck-related concussion every 7 games[b]

[a] CIs: confidence intervals.
[b] N.B. different denominator.

limited. For the purposes of this study, the principle of "recognise and re-move" was employed to assess criteria whereby, if there was suspicion that any criterion was met, the player should be removed as a precaution. Although this may have inflated the concussion rate, in the context of a setting without enhanced care and no head injury assessment in place, this is appropriate.

A 2019 systematic review of injuries of women's 15-a-side rugby reported a rate of 19.6/1000 h (95 % CIs: 17.7–21.7[2]) with values ranging from 3.6 to 37.5/1000 h. The current study demonstrated an all-injury rate ~ 3 times higher than the highest value reported in this systematic review and a medical attention rate ~ 2.5 time higher, with medical attention rates being closer in contrast to professional men's rugby [87/1000 h (95%CIs: 82–92)[20]] compared to professional women [35/1000 h (95%CIs: 30–42)[21]]. However, some of the challenges outlined regarding the diagnostic threshold for injury may be responsible for this difference. The rate of suspected concussion in this study was also higher than even the highest rate of concussion in Rugby Union which is in professional men [20.9/1000 h (95 % CIs: 17.9–24.3)[22]]. Despite the rates of suspected concussion being higher than those previously reported, the proportion all injuries reported as concussion (26 %), was similar to that previously reported. One possible reason for the higher rates of injury is the compact nature of the league from which the data were captured. The varsity rugby season involves teams playing 4–6 regular season games (in addition to two potential playoff games) between September and November and while the match schedule itself is normal compared to other leagues (weekly games), the nature of student sport means a short pre-season period (usually 4 weeks). It has previously been shown in Rugby League[23] and soccer[24] that a higher number of pre-season training sessions is associated with lower in-season risk. Therefore, it is postulated that the short pre-season period may not be sufficient to meet the demands of returning to a contact sport, where return-to-contact frameworks suggest a 6-week training period.[25] What is evident, is that even with consideration for the

difference in the methods with which these data were collected, the rate of suspected injury and concussion appears high. However, the injuries recorded in this study may not be documented in other surveillance settings if they did not lead to time-loss.

There is currently a dearth of information regarding the propensity of injury per 1000 match events. However, given the continual evolution of match play patterns, it has been noted that reporting of injury propensity would be useful to identify whether certain match events are becoming more hazardous, or if, for example, the increase in tackle events is leading to a rise in injuries.[22] Data from the professional men's' game indicate the propensity of injury in tackle events was 7.5 injuries/1000 tackles during the 2018/19 season.[26] In comparison, this study reported 11.2 suspected injuries/1000 tackles (95 % CIs: 9.5–13.2: Table 2). Again it must be stressed that the injuries being recorded are 24 h time-loss injuries by Kemp et al[26] compared to those captured through video analysis, however it is noteworthy that the rate of injury related to the tackle is high, with 67 % of all injuries and 78 % of concussions caused by the tackle in this cohort (Fig. S1). Concerningly, this means that on average there are over 3 tackle-related suspected injuries per game.

In the context of concussion recognition outside of the professional game, any clinical suspicion of a concussion should lead to a player being removed from play. One of the most concerning findings of this study is the low proportion of players removed from play with a suspected concussion (39 %) who met a "recognize and remove" criteria. Professional men's rugby has seen a series of additions to aid concussion recognition with the introduction of the Head Injury Assessment (HIA) process (2012), mandatory concussion education (2014/15), real time video monitoring as part of the HIA process (2016) and independent match day doctors (2019), which have contributed to a 4-fold increase in the number of concussions being recorded between 2008/09 and 2018/19.[22] Despite this, in lower levels of the game, the "recognise and remove" criteria, in conjunction with tools such as the
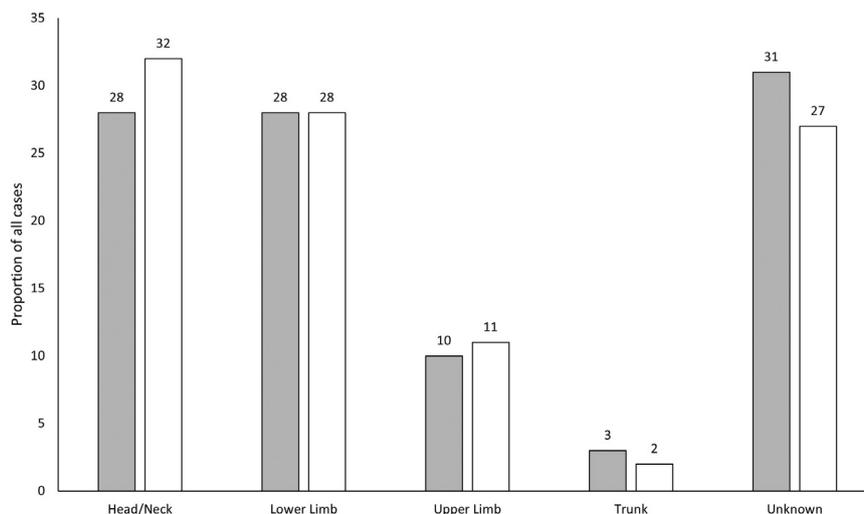
Fig. 1. Proportion of suspected injury by location: grey bars = all injuries; white bars = medical attention injury.

Concussion Recognition Tool-5,[14] have been heavily relied on, aside from self-reporting to medical staff. In this study, it has been shown that criteria for recognise and remove are apparent (as documented by the research team), however this does not translate into the appropriate removal of players and therefore there may be more need for education and training for on-field recognition of suspected concussion events by coaches, therapists, and referees.

The primary limitation of this study is that only one video angle was available and often was taken with a wider-angle view for performance analysis purposes. Secondarily, in the case of suspected concussion recognition, clinical suspicion by one medical staff member would be grounds for the recognise-and-remove criteria to be used. However, given the limitations, we have been more conservative in that half of medical staff were required to consider the event to be an injury for the first ~60 clips and 2/3 coders were required to have said yes for all remaining clips. A final limitation is the inclusion of non-medically trained coders. However, the two coders were experienced and well-trained kinesiologists, familiar with concussion protocols and rugby.

5. Conclusions

This study provides useful data in the context of the women's game and highlights high rates of suspected injury and concussion in non-professional leagues. The rates and number of suspected injuries related to the tackle are somewhat higher than previously noted in the men's game, but it is important to note that the present study employed different methods to that used to generate most of the data for the men's game. Of note is the high proportion of players not removed following a potential suspected concussion event, with an apparent need for further education/training with all pitch side stakeholders. This study provides valuable insight for the women's game and used innovative video analysis methodology to ensure women's data is accounted for in future prevention strategies.

Declaration of Interest Statement

Jon Patricios serves as a concussion advisor and independent concussion consultant to World Rugby. The remaining authors have no financial interests or benefits to disclose as a direct result of this work.

Confirmation of Ethical Compliance

This study received ethical approval from the Conjoint Health Research Ethics Board at the University of Calgary (Ref: REB20-1443). See below the recent renewal of our ethics certificate.

Data availability statement

There is no dataset publicly available for this study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jsams.2022.07.008.

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