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Original research

The propensity of non-concussive and concussive head contacts during elite-level women's rugby league matches: A prospective analysis of over 14,000 tackle events

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ABSTRACT

Objectives: Identify the frequency, propensity, and factors related to tackle events which result in contact with the head in elite-level women's rugby league.
Design: Prospective video analysis study.
Methods: Video footage from 59 Women's Super League matches were analysed ($n = 14{,}378$ tackle events). All tackle events were coded as no head contact or head contact. Other independent variables included: area contacting head, impacted player, concussion outcome, penalty outcome, round of competition, time in match and team standard.
Results: There were 83.0 ± 20.0 (propensity 304.0/1000 tackle events) head contacts per match. The propensity of head contact was significantly greater for the tackler than ball-carrier (178.5 vs. 125.7/1000 tackle events; incident rate ratio 1.42, 95 % confidence interval 1.34 to 1.50). Head contacts occurring from an arm, shoulder, and head occurred significantly more than any other contact type. The propensity of concussions was 2.7/1000 head contacts. There was no significant influence of team standard or time in match on the propensity of head contacts.
Conclusions: The observed head contacts can inform interventions, primarily focusing on the tackler not contacting the ball-carrier's head. The tackler's head should also be appropriately positioned to avoid contact with the ball-carrier's knee (highest propensity for concussion). The findings are consistent with other research in men's rugby. Law modifications and/or enforcement (reducing the number of un-penalised head contacts), concurrent with coaching interventions (optimising head placement or reducing the head being contacted) may help minimise head contact risk factors for women's rugby league.

Practical implications

- The present study identified that 27.6 % of tackle events resulted in contact being made directly to the head of a player, which may be reduced via improved tackle technique and stricter on-field sanctions.

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- An opportunity exists to reduce the incidence of head contact by ensuring the 'high tackle' law is enforced. By potentially increasing the on-field and post-match sanctions for high tackles and head contact, player and coach behaviours may change.[30]
- With coaching and medical staff rating tackle technique as the most important and feasible risk factor for injury,[25] improving tackle technique could mitigate head contacts for both the tackler (e.g., their head placement) and ball-carrier (e.g., body area tackler makes contact with).
- The aforementioned intervention strategies offer an opportunity to effectively mitigate head contact and concussion risk in elite-level women's rugby league.

1. Introduction

Rugby league is a contact sport, whereby players frequently undertake tackles during training and matches.[1] The number of tackles per player per match are similar between men's (4–41 tackles per player per match)[2,3] and women's (4–26 tackles per player per match)[4] rugby league. The tackle has the highest risk of injury, with 38–96 % of injuries occurring during tackles in men's and women's rugby league.[5,6] Concussion is also a specific risk for rugby league, with a similar incidence of concussion reported for men's and women's rugby league (7.7 and 6.1–10.3 concussions per 1000 match hours).[7,8] An increased investment into women's rugby league internationally has seen the development of elite competitions in England (Women Super League [WSL]) and Australia (National Rugby League Women [NRLW]), yet limited research has been undertaken in women's rugby league, specifically around the tackle.[9,10]

Dangerous, careless or intentional contact to a players head during the tackle is against the laws of rugby league and could be a risk for concussion.[8,11] During a tackle, contact to the ball-carrier's head is considered a 'high tackle' and should be penalised by the match official. However, direct head contact can still occur in rugby league, yet it is unclear how many head contacts lead to a concussion and what factors increase their likelihood.[11,12] Understanding the propensity of head contact and risk factors can inform policy, coaching and player education initiatives, specific to elite women's rugby league players.[13,14]

The proportion of tackle events that result in head contact in women's rugby league is unknown. Determining the occurrence of concussion, risk factors, mechanisms and the overall risk in women's rugby league is of high importance for all stakeholders.[9] The aims of this study were for the first time to 1) identify the frequency, propensity and mechanisms of tackle events that resulted in non-concussive or concussive contact with the head and 2) describe the influence of the time in match, round of competition and team standard on the frequency and propensity of non-concussive or concussive head contacts within the WSL.

2. Methods

Video footage of matches ($n = 59$) from the WSL 2021 season were accessed via the Rugby Football League (RFL) online sharing platform. Six matches were excluded due to either; the video footage not being available or the angle of the footage being too wide, too high, or unclear to accurately code, which was determined by the video analyst. Clinically diagnosed concussive incidents ($n = 15$) were recorded by WSL club medical staff as part of the 2021 season injury surveillance project and provided by the RFL. Three concussions were excluded given corresponding match footage was not available due to the aforementioned reasons. Therefore, the study included 53 matches and 12 concussions. This study received ethics approval from Leeds Beckett University, Local Ethics Committee (reference: 101063).

Video footage of matches were analysed and coded via Sports Code elite (v.6.5.1) using an Apple iMac (Apple, USA) by an experienced coder (MH: 10 years as a video analyst in professional rugby). The analysis software allowed control over the time lapse during each tackle event, which was recorded and saved into a database. The analyst could slow down the motion of the footage to 25 frames/s. Events were coded using both characteristics and definitions described in previous research[15] and specifically for this study (outlined below).

All tackle events (whether successful or unsuccessful) were coded as either a tackle event involving contact to the head (i.e., head contact) or not involving head contact (i.e., no head contact), and subsequently labelled as ball-carrier or tackler. Head contact was defined as a '*direct contact to a player's head, resulting in a visible change in trajectory of the head*'. No indirect head contacts (e.g., whiplash) were coded. Head contact types were coded as: head(-to-head), shoulder, arm, torso, hip, upper leg, knee, lower leg, ground and equipment (e.g., post/ball).[15] All penalties awarded by the match-official for a high tackle were coded. Tackle events resulting in a subsequent clinician diagnosed concussion (as per the 2021 season injury surveillance project) were also coded. Tackle events were characterised by match, round of competition, time in match (stratified by match quarters: 0–20, 20–40, 40–60 and 60–80 min), and team standard (top vs. top, top vs. bottom and bottom vs. bottom). Team standard was categorised by final league position in the WSL table. Top was defined as a team finishing in the top five and bottom was defined as finishing in the bottom 5 teams in the 2021 WSL table. These were consistent throughout the season. For example, halfway through, and at the end of the season the same teams were in the top 5.

Descriptive statistics (counts and mean $\pm$ standard deviation [SD]/match) were used to summarise the number of head contacts. Propensity of head contact was expressed as the number of head contacts/1000 tackle events with 95 % confidence interval based on a Poisson distribution.[16] Propensities for player role (i.e., ball-carrier/tackler) and head contact type were calculated with the total number of tackle events as the denominator. Time in match, round and team standard propensities were calculated with a denominator specific to those circumstances (Supplementary Tables 2 and 3). Similarly, concussion propensities were calculated as a result of those specific head contact event exposures (e.g., concussion caused by head-to-head contact / (total head-to-head contacts / 1000)). Concussion propensity was expressed as the number of concussions/1000 head contacts with 95 % confidence interval based on a Poisson distribution. Instances of head contacts occurring to the ball-carrier and tackler per match were identified separately and stratified by areas of the body or surface contacting the head. Differences were deemed to be significant if the 95 % confidence intervals (CIs) of comparison groups did not cross.[16] Incident rate ratios (IRRs) and 95 % CIs were calculated to provide a magnitude of difference between comparisons. Analyses were conducted in R (v4.1.1; R Core Team 2021).

To assess intra-coder reliability, two randomly selected matches were analysed twice. The second process of coding was performed at least seven days after the first.[17] Cohen's Kappa coefficient (κ) was used to evaluate the intra-reliability.[18] Kappa values between 0.01 and 0.20 indicate none to slight, 0.21 and 0.40 fair, 0.41 and 0.60 moderate, 0.61 and 0.80 substantial and, 0.81 and 1.00 almost perfect agreement between repeated measures.[19] Intra-coder reliability: head contact presence ($k = 0.971$); head contact area agreement ($k = 0.886$); identifier agreement ($k = 0.819$).

3. Results

A total of 14,378 tackle events were analysed from the video footage of 53 matches. There were 271 $\pm$ 35 tackle events per match. The number of tackle events resulting in head contact were 75.5 $\pm$ 17.4 per match (propensity 278.2 [246.5–312.9]/1000 tackle events), which was 27.6 % of all tackle events. The total number of head contacts per match was 83.0 $\pm$ 20.0 (304.0 [270.8–340.2]/1000 tackle events) (*greater than the number of tackle events resulting in head contact due to head-to-head contact events resulting in two head contacts*). The number and propensity of head contacts per match to the ball-carrier and tackler were 34.1 $\pm$ 9.7 (125.7 [104.7–149.8]/1000 tackle events) and 48.4 $\pm$ 12.9 (178.5 [153.2 to 206.7]/1000 tackle events), respectively.

The tackler had a statistically significantly (IRR = 1.42, 95 % CI 1.34–1.50) higher propensity of a head contact than the ball-carrier.

Fig. 1 shows the mean ± SD of head contacts occurring to the tackler and ball-carrier for areas of the body or surface contacting the head, ranked highest to lowest (see Supplementary Table 1). Fig. 2a shows the propensity (95 % CI) of each head contact type for each contact area, ranked highest to lowest. The propensity of a head contact to the arm, shoulder and head was significantly higher than any other head contact mechanism (IRR range, 95 % CI = 2.0, 1.9–2.1 head vs. ground, and 63.9, 60.5–67.4 arm vs. equipment: Supplementary Table 4). As well as the propensity of a head contact to the ground, hip, upper leg and torso was significantly higher than head contacts to the lower leg, knee and equipment (IRR range, 95 % CI = 5.6, 5.3–6.0 torso vs. lower leg, and 18.8, 17.8–19.8 ground vs. equipment: Supplementary Table 4). Tackle events resulting in head-to-head contact occurred between the ball-carrier and tackler on 94.5 % of occasions, the other 5.2 % and 0.3 % occurred between a tackler and teammate, and a ball-carrier and teammate, respectively.

The propensity of concussion was 0.8 (0.0–5.3)/1000 tackle events (n = 12), which was 0.6 (0.0–4.9) and 0.2 (0.2–4.1)/1000 tackle events for the tackler (n = 9, 75.0 % of concussions) and ball-carrier (n = 3, 25.0 % of concussions). The propensity of concussions was 2.7 (0.5–8.4)/1000 head contacts, which was 3.5 (0.9–9.5) and 1.7 (0.2–6.7)/1000 head contacts for the tackler and ball-carrier.

Tackle events resulting in concussion were due to head contact from the arm (4.0 [1.1–10.0]/1000 arm-to-head contact events), shoulder (2.2 [0.3–7.5]/1000 shoulder-to-head contact events), knee (25.6 [16.7–37.7]/1000 knee-to-head contact events), ground (5.3 [1.8–12.2]/1000 head-to-ground contact events), and torso (3.5 [0.8–9.5]/1000 head-to-torso contact events) (Fig. 2b). There was a significantly higher propensity for concussion to occur from knee to head contacts than any other mechanism (IRR range, 95 % CI = 4.8, 2.2–10.4 knee vs. ground, and 11.7, 5.5–24.7 knee vs. shoulder: Supplementary Table 5).

The propensity of concussions occurring within the first, second, third, and fourth quarters of a match was 2.9 (0.6–8.7 [n = 3, 25.0 % of concussions]), 1.0 (0.0–5.5 [n = 1, 8.3 % of concussions]), 4.6 (1.4–11.0 [n = 4, 33.3 % of concussions]), and 3.8 (1.0–9.9 [n = 4, 33.3 % of concussions])/1000 head contacts. The propensity of concussion during top vs. top, top vs. bottom and bottom vs. bottom matches was 3.5 (0.8–9.5 [n = 4, 33.3 % of concussions]), 3.0 (0.6–8.6 [n = 4, 33.3 % of concussions]), and 2.7 (0.5–8.4 [n = 4, 33.3 % of concussions])/1000 head contacts.

The number of penalised high tackles/match was 2.1 ± 1.8 (7.6 [3.18–15.2]/1000 tackle events). The propensity of penalised high tackles/1000 head contacts was 24.9 (16.1–36.8), which equates to 2.7 % of the tackle events resulting in a head contact. The propensity of penalised high tackles was 59.9 (45.7–77.1)/1000 head contacts occurring to the ball-carrier (6.0 %).

Fig. 2c and d shows the propensity/1000 tackle events (95 % CI) of head contacts occurring across time in match and team standard (Supplementary Tables 2 & 3). There were no significant differences in the propensity of tackles resulting in head contacts between quarters of a match. There were no significant differences in the propensity of tackle events to cause head contacts between team standards. Fig. 3 shows the mean ± SD/match and propensity/1000 tackle

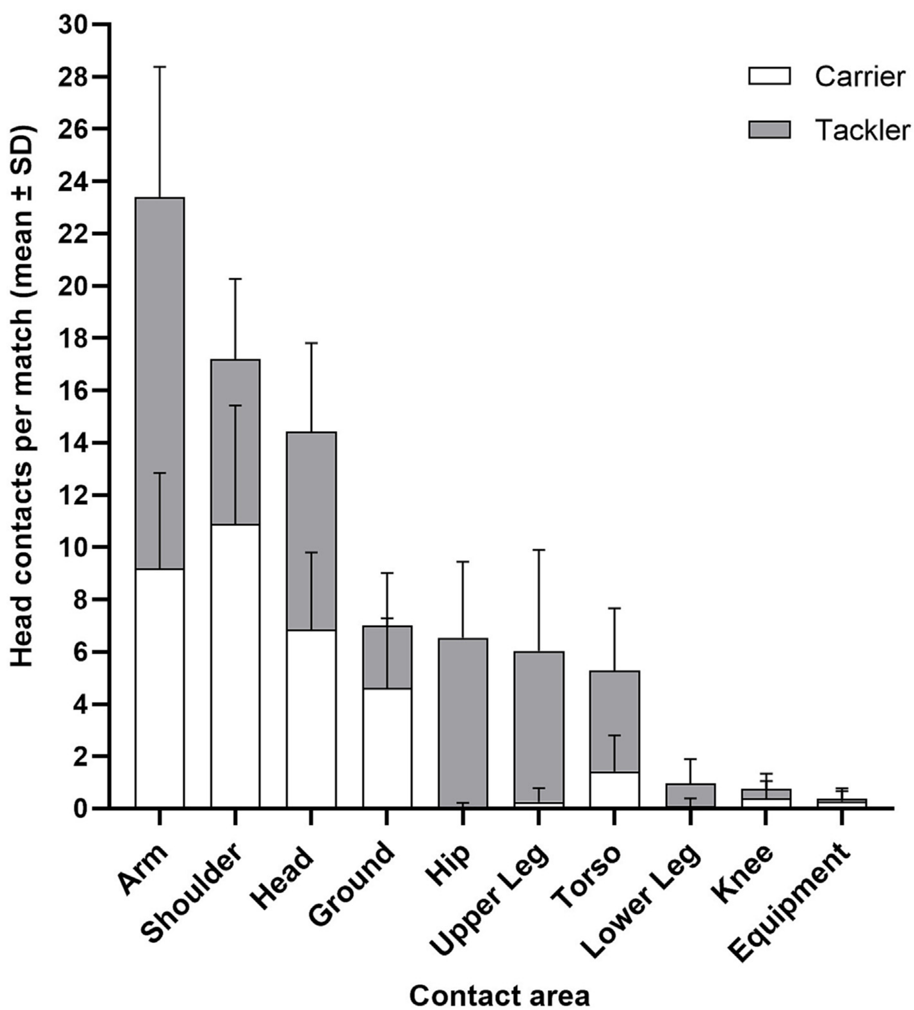

Fig. 1. Mean ± SD of head contacts occurring/match to a ball-carrier and tackler by contact area.

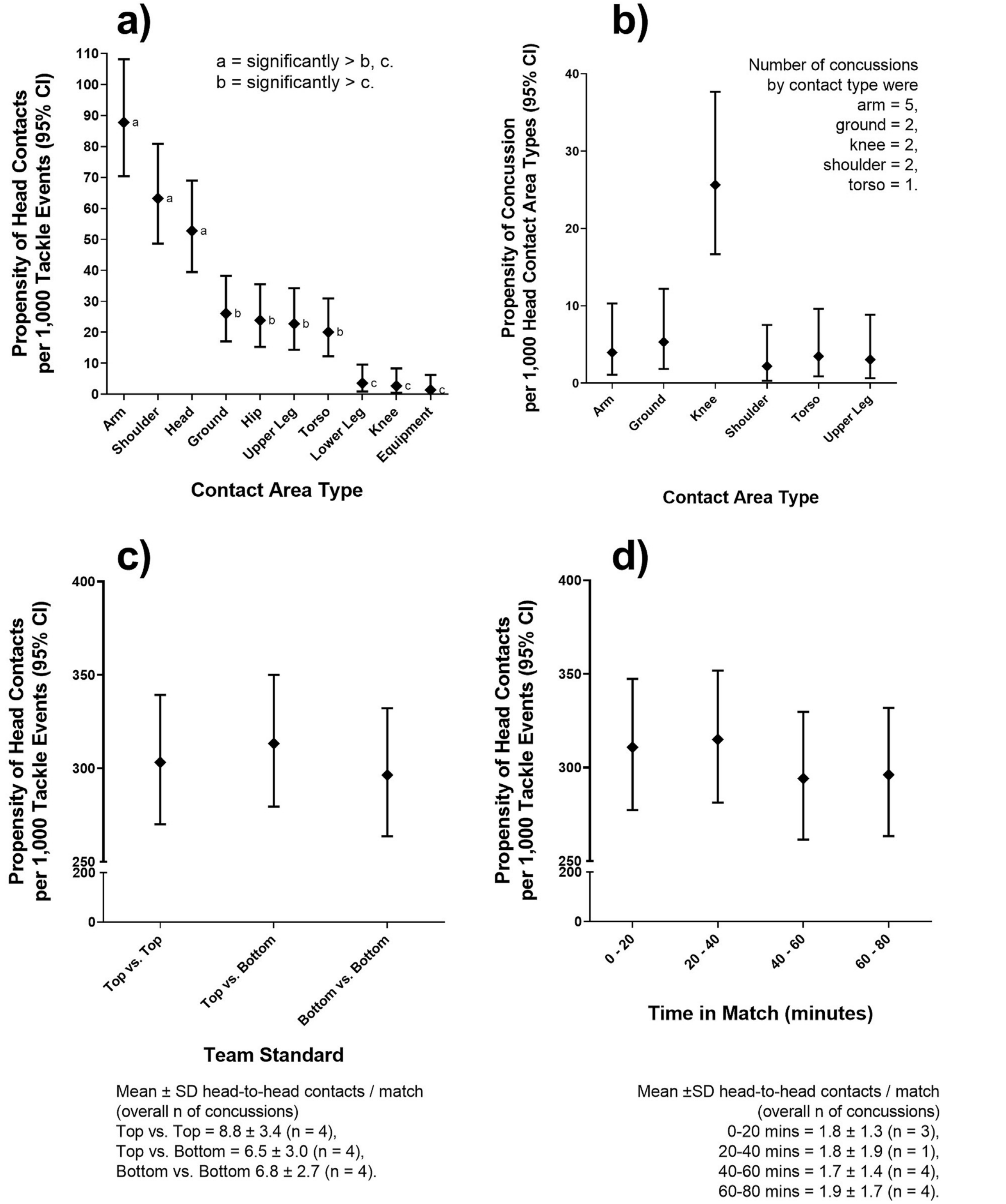

Fig. 2. Propensity (95 % CI) of (a) head contact/1000 tackle events by contact area type, (b) concussion/1000 head contacts for each contact area type, (c) head contact/1000 tackle events by time in game, (d) head contact/1000 tackle events by team standard.

events (95 % CI) of head contacts occurring in each round of competition. There were significant differences in the propensity of head contacts to occur between rounds of competition, with the largest difference identified in round 2 vs. round 8 (IRR = 2.0, 95 % CI 1.4–3.0) (Fig. 3).

4. Discussion

This study aimed to investigate the frequency, propensity and mechanisms of tackle events resulting in head contacts and concussions across a season of elite-level women's rugby league for the first time.

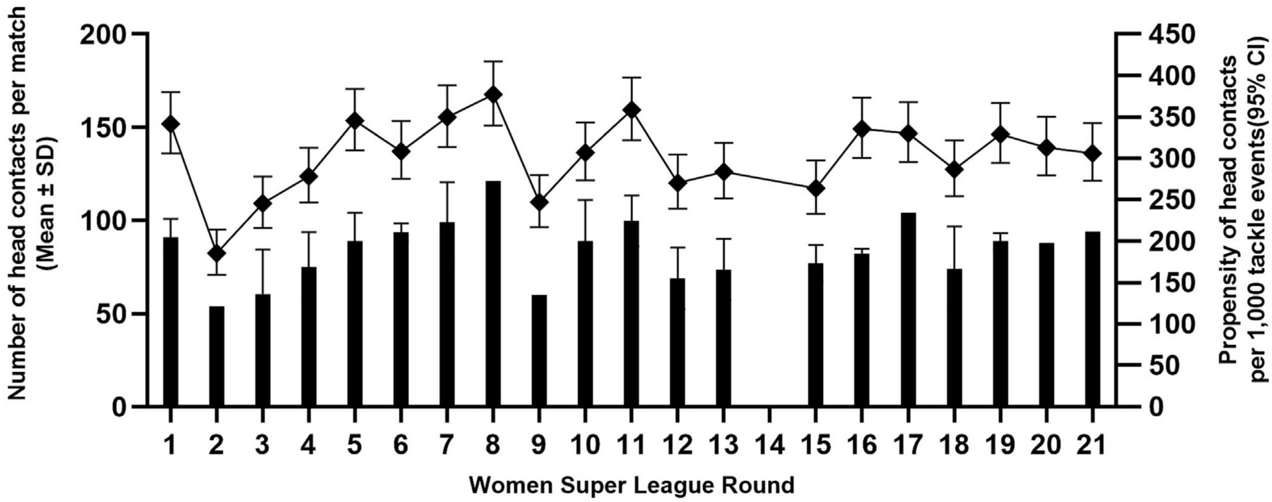

Fig. 3. Mean ± SD head contact/match and propensity (95 % CI) of head contacts/1000 tackle events by round of competition. No match footage was available for round 14.

This study found almost a third (28 %) of all of tackle events in elite-level women's rugby league matches resulted in head contact, with the propensity of head contact for the tackler 1.42 times higher than for the ball-carrier. These findings are consistent with men's rugby union[16] and men's rugby league[20] where the tackler had a greater risk of head injury/Head Injury Assessment (HIA) than the ball-carrier. This study found that head contact occurred from the arm, shoulder and head significantly more than the lower leg, knee and equipment, which may be modifiable by coaching (e.g., tackle technique focusing on tackler head position and point of contact on ball-carrier) and match official (i.e., penalising illegal play) interventions, specific for women's rugby league. Significant differences in the propensity of head contacts were found between rounds of competition, however no significant differences were observed by team standard or time in match, which are relevant when reviewing competition structures. The findings from this study can be used to reduce the incidence of head contact in women's rugby league during matches, which is a priority for sports to minimise overall head acceleration exposure and concussion risk.[21,22]

In women's rugby league matches, head contact occurred from the arm, shoulder or head significantly more than the lower leg, knee and equipment. Based on these findings it is vital interventions are implemented to reduce head contact from the arm, shoulder and head. Whilst other head contact types were significantly more likely to occur than head-to-knee contacts, this should also be considered during interventions (e.g., coaching of tackle technique) given the propensity for head-to-knee contacts was 4.8–11.7 times higher for concussion than any other mechanism. Other studies in male rugby union and rugby league have also reported that high (e.g., head-to-head, shoulder) and low (e.g., hip, ground and knee contacts) contacts during a tackle were significantly more likely to result in a HIA and/or a concussion compared to head-to-trunk contact.[11,20,23] Tackle technique coaching interventions focusing on contact with the ball-carrier's torso (e.g., below the shoulder and above the hip) should be encouraged which may reduce the risk of head impacts in women's rugby league.

Of the 12 concussions included in this study, 75 % were experienced by the tackler. The propensity of concussions/1000 tackle events identified in women's rugby league was less than women's varsity rugby union (3.4 vs. 0.8),[24] although this was based on a different definition (suspected concussions in rugby union vs. clinically diagnosed concussions in rugby league). A pooled analysis of the rate of concussion in women's rugby league found 10.3 per 1000 match hours with an average number of days lost of 33,[7] highlighting the need to reduce concussion in women's rugby league from both player welfare and performance (e.g., match and training availability) perspectives. Although women are more open to reporting concussions than men, underreporting and underdiagnosis still exist in female athletes which may influence the number of clinically diagnosed concussions in the WSL.[13]

The propensity of head contacts was not significantly different between team standard (Fig. 2d) and time in match (Fig. 2c), which is an important finding when considering competition structures. In a recent Delphi study identifying injury risk factors specific to women's rugby league,[25] team standard (i.e., top vs. bottom teams) was thought to influence injury rates given the potential physical and technical differences,[26] although the findings of this study indicate that this may not be true for head contact and concussion. Despite this, there were significant differences in head contacts between rounds of competition (Fig. 3), although it was unknown why this occurred. One explanation may be that the WSL did not take place during 2020 due to COVID-19, therefore earlier in the season players may have demonstrated underdeveloped tackle technique, from both physical and decision-making perspectives. Given tackle technique was identified as the most important and feasible injury risk factor to reduce injuries in women's rugby league,[25] this highlights the need for coaching interventions promoting good tackle technique. In addition, match officials may have been refamiliarising themselves with refereeing women's rugby league, which may explain the number of tackles involving head contact to the ball-carrier that were penalised (6.0 %).

The laws of rugby league prohibit dangerous, careless, or intentional contact with a player's head in a rugby league match. The current study did not identify the frequency of ‘high tackles’ that were not penalised. However, there is a clear discrepancy between the number of penalised high tackles and head contacts (2.1 ± 1.8 vs. 83.0 ± 20.0 per match). Whilst this study did not evaluate which tackles should have been penalised (e.g., tackler head contact with the ball-carriers hip should not have been penalised), it could be argued that contact with the ball-carrier's head by the tackler's arm (9.2 ± 3.7 per match) should have been penalised. This suggests that reinforcing the high tackle law with appropriate sanctioning could potentially minimise head contact and reduce the concussion risk in women's rugby league. In male rugby union, high contact with the ball-carrier is 4.25 times more likely to cause a HIA compared to low contact,[12] again reinforcing the need for stricter sanctioning of the high tackles to protect the ball-carrier and tackler.

This study was not without limitation. The current study was conducted over a single season of elite level women's rugby league, following the COVID-19 suspended 2020 season. The sample of concussive incidents was small but still representative of a WSL season. Within women's rugby league, medical staff do not have side-line (i.e., in-game/live) video replay available which may lead to potential concussive incidents being missed.[27] Of the 15 concussive incidents diagnosed, three were excluded from the analysis due to match footage being unavailable for video analysis (as outlined in the Methods section). Furthermore, given the subjective nature of quantifying head contacts from video footage, some head contacts may not have been visible. This study did not quantify inertial head loading (indirect head accelerations) or head contact magnitudes, therefore head acceleration exposure in women's rugby league players remains relatively unknown. A combination of video analysis and instrumented mouthguard technology[28] used in future research would provide a greater level of understanding of head acceleration exposure of elite-level women's rugby league.[29] Future research should also examine other tackle characteristics including the height of the tackle, the tackler and ball-carrier contact/impact body position, the speed of the players, and the type of tackle to identify the roles of these specific tackle characteristics and their potential association with tackle events that result in head contact, and concussion. Moreover, investigating referee penalty decisions and head contacts is also a priority for future research.

5. Conclusion

This is the first study to quantify the frequency and propensity of head contact and concussive and non-concussive tackle events over a season of elite-level women's rugby league. The tackler is at greater risk of head contact and concussion than the ball-carrier. The propensity of head contact was higher from the shoulder, head, and arm than any other mechanism, however the propensity for concussions was highest for head-to-knee contact. As such tackle interventions should focus on contact with the ball-carrier's torso (e.g., below the shoulder and above the hip) to reduce the risk of head impacts in women's rugby league. Furthermore, the sanctioning by match officials of tackles resulting in contact with the head should also be considered. This study provides information on the specific risk factors of head contacts in women's rugby league, which can be used for coaching interventions and by match officials (e.g., on-field and post-match sanctioning), along with potentially informing law modifications to reduce head contact in women's rugby league.

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Confirmation of ethical compliance

This project was approved by Leeds Beckett University, Local Ethics Committee (101063).

Patient and public involvement

Patients and/or the public were not involved in the design, conduct, reporting, or dissemination plans of this research.

CRediT authorship contribution statement

Mily Spiegelhalter: Conceptualization, Methodology, Validation, Formal analysis, Writing – original draft, Writing – review & editing, Visualization, Project administration. **Sean Scantlebury:** Conceptualization, Methodology, Supervision, Writing – review & editing, Project administration. **Omar Heyward:** Conceptualization, Methodology, Supervision, Writing – review & editing, Project administration. **Sharief Hendricks:** Conceptualization, Methodology, Supervision, Writing – review & editing. **Cloe Cummins:** Conceptualization, Methodology, Supervision, Writing – review & editing. **Andrew J. Gardner:** Writing – review & editing. **Matt Halkier:** Methodology, Investigation, Validation, Resources. **Shreya McLeod:** Writing – review & editing. **Gemma Phillips:** Writing – review & editing. **Cameron Owen:** Software, Formal analysis, Data curation. **Ben Jones:** Conceptualization, Methodology, Supervision, Writing – review & editing, Project administration.

Data sharing

All data relevant to the study are included in the article or uploaded as Supplementary information.

Declaration of interest statement

MS PhD and OH's research fellowship is part-funded by Leeds Rhinos. BJ is employed by Leeds Rhinos and Premiership Rugby in a consultancy capacity. GP and BJ are employed in a consultancy capacity by the Rugby Football League. SS and CO's research fellowship is part-funded by the Rugby Football League. OH's research fellowship is part-funded by the Rugby Football Union. GP is a contracted Doctor by a SL club. CC received support in the form of research funding from the National Rugby League. AJG serves as a scientific advisor for hitIQ, Ltd. He has a clinical practice in neuropsychology involving individuals who have sustained sport-related concussion including current and former athletes. He has been a contracted concussion consultant to Rugby Australia. He is a member of the World Rugby concussion working group. He is a member of the Australian Football League concussion scientific advisory committee. SM declares no competing interests.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jsams.2023.03.003.

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