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Original research

The epidemiology of head impacts, head injury assessments, and concussions in the National Rugby League: A study from the SCRIMMAGE database

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ABSTRACT

Objectives: Rugby League is a popular collision sport with an inherent risk of concussion. Management systems have been introduced at the elite level to detect and manage head impacts with the potential for concussion; however, little is known about the epidemiology of these events. This study aimed to describe the risk and incidence of head impacts, head injury assessments, and concussions in the National Rugby League.
Design: A retrospective cohort study.
Methods: Official National Rugby League player data from the 2017 to 2023 seasons was linked to the SCRIMMAGE registry of head impacts, to provide a definitive database of exposure (match participation, player-match hours) and outcomes (head impacts, head injury assessments, and concussions). The risk and incidence of each outcome were calculated, overall and across each season.
Results: Between 2017 and 2023 892 individual players participated in at least one game, with a total of 48,113.45 exposure hours. There were 5274 head impacts detected, resulting in 1849 head injury assessments, and 665 concussions. Incidence rates of head impacts, head injury assessments, and concussions per 1000 player-match hours were 109.62 (95% confidence interval: 103.47–116.13), 38.43 (95% confidence interval: 35.55–41.55), and 13.82 (95% confidence interval: 12.54–15.23) respectively.
Conclusions: Head impacts, head injury assessments, and concussions were common events in National Rugby League, but occurred at comparable, or relatively lower, rates than similar collision sports. This burden of injury justifies the comprehensive National Rugby League concussion management system and supports ongoing efforts to mitigate the risk of head impacts, balanced against sporting considerations.
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Practical implications

- Head impacts and concussion-related events are common in the NRL, with many players experiencing at least one head impact or head injury assessment during a season, and a notable minority sustaining concussions.
- Despite being frequent, the rate of concussion in the NRL appears similar to or lower than other comparable contact sports, suggesting current game rates are not unusually high.
- These findings support the value of the NRL's comprehensive concussion monitoring and management system, whilst highlighting the need for continued efforts to reduce head injury risk.

1. Introduction

Rugby league is a collision sport played in over 70 nations globally. It is played professionally at the highest level in the National Rugby League (NRL) in Australia, where it is the most popular sporting code with over 175 million annual television spectators.[1] During match play there is a risk of head impacts and consequent concussive head injury.[2–4] Concussion incidence rates between 14.8[5] and 28.3[6] per 1000 player hours in professional men's rugby league, 14.3[3] per 1000 player hours in academy rugby league, and 9.4[7] per 1000 player hours in professional women's rugby league have been reported.

Head impacts and concussion are a prominent issue in rugby league, of interest to players and supporters, and subject to media and legal scrutiny.[8] To improve the detection and treatment of head injuries at the elite level, the NRL introduced a concussion management system in 2014. This includes visual and video detection of head impacts, head injury assessment (with immediate removal from play or off-field

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concussion screening ('head injury assessment, HIA')), standardised post-match medical reviews, and return to play protocols.[9] However, beyond the video analysis of concussion in rugby league, revealing that the tackler is more frequently concussed than the ball carrier, and that head-to-head and head-to-shoulder contact in upper body tackles, and head-to-hip contact in lower body tackles are the most frequent mechanisms for head impact events in concussed tacklers,[5,10] there is a paucity of research describing the epidemiology of head impacts and head injuries in rugby league generally, and for the NRL specifically.

Understanding the frequency and burden of head impacts and concussion in NRL is important to define the risk posed to players, observe secular trends, deduce the effect of rule and interventions/management changes, and establish a baseline to evaluate future initiatives to reduce concussion in rugby league. This brief descriptive study therefore aimed to provide an epidemiological overview of NRL head impact events, HIAs, and concussions, including describing the frequency and incidence rate of these events.

2. Methods

2.1. Study design

A retrospective cohort study was performed to determine risk and incidence rate of head impacts, HIAs, and concussions in the men's NRL premiership.

2.2. Study setting and population

The study was conducted during the 2017 through 2023 NRL Premiership seasons. All players participating in any competition match, regardless of duration of play, were included. Training sessions were not studied. During the study period the number of eligible teams, rounds, and games varied by season as detailed in Table 1.

Head impacts, defined as a direct or indirect force resulting in sudden contact or change of direction to the head, occurring during games were detected by the NRL sideline surveillance system and injury surveillance bunker. These processes evolved during the study period and have been outlined in detail elsewhere.[11] Briefly, between 2017 and 2018 head impacts were visually identified, recorded ('tagged'), and evaluated from the sideline by team medical staff using broadcast television footage. From 2019, these processes were augmented by a centralised 'injury surveillance bunker' (ISB), with additional 'concussion spotters' using Hawk-Eye's multi angle video review technology.[12] At this time the ISB identified head impacts and alerted club medical staff to view sideline video replays. From the 2022 season, the sideline surveillance system was operated exclusively from the central ISB, served by an independent medical doctor who directly evaluated head impacts and determined further action.

Direct head impacts resulting in a concern of possible concussion, either visualised directly from the sideline, or identified by the injury surveillance bunker, were subsequently evaluated by the team doctor at the match according to NRL 'Head Injury Assessment' (HIA) procedures. During the 2017 through 2021 seasons, this was at the discretion of the sideline team medical staff. From 2022, the ISB Medical Officer had the ability to instigate further evaluation via direct contact with the match referee or team medical staff.

Match day injury surveillance is guided by the Category 1 and Category 2 signs and symptoms of potential concussion, some of which are video signs of potential concussion monitored and identified by the central ISB. The presence of clear signs of concussion (i.e., 'Category 1 signs' e.g., ataxia) mandates immediate removal from the field with no return to play. Visual signs that could indicate the potential for concussion (i.e., 'Category 2 signs', e.g., slow to get up) require player removal for a 15 minute off-field concussion screening assessment using the latest iteration of the Sports Concussion Assessment Tool (SCAT; i.e., the Off-Field Assessment items [Steps 1–4]),[13] administered by the club medical officer. If the assessment results are interpreted as being of concern or suggestive of concussion, the player is permanently removed; otherwise, they can return to play.

All players entering the HIA process undergo a series of structured and standardised post-game medical assessments performed by team doctors. These occur post-game and at 48 h following the HIA, consisting of a detailed clinical assessment including use of the most recent SCAT.[13] A player can be diagnosed with a concussion at any point during this process. Following a diagnosis of concussion players enter a Graduated Return-To-Play Strategy consisting of five stages, increasing from symptom-limited activity to full contact training. From the 2022 season, the earliest a player is eligible for a full return to unlimited play is on the 11th day post concussion.

2.3. Data collection

Official NRL player data was linked to the Scrutinising Contact Replays: Investigating Mechanisms, Management, and Game Exposures in Australian National Rugby League (SCRIMMAGE) registry of head impacts, to provide a definitive database of exposures (match participation, athletic exposures (i.e., games), and player-match hours) and outcomes (head impacts, HIAs, and concussions).

The NRL compiles official statistics of player line-ups, positions, and minutes played for every game, recorded prospectively by match officials. The SCRIMMAGE database has been described in detail previously.[14] Briefly, it includes consecutive head impacts detected by the NRL concussion management system during matches over seven NRL Premiership seasons, 2017 through 2023 inclusive. From 2017 to 2019 all head impacts were identified by notification from the Chief Medical Officer of the NRL, with video footage of the head impact obtained through the NRL's Digital Press Pass subscription. Subsequently (2020–2023), in-game email alerts for each head impact event were provided from the NRL with video clips of the events available for review through NRL stored in IT systems.

Once case videos were obtained, coding of player, match, tackle, and other event characteristics was completed (i.e., retrospectively,

Table 1
Player exposure and events between 2017 and 2023 NRL seasons.

Season	Teams	Rounds[a]	Games[b]	Hours of gameplay	Individual players	Player exposure hours	Approximate tackles per game[c]	Head impacts	HIAs	Concussions
Overall	17	201	1387	1849.33	892	48,113.45	634	5274	1849	665
2017	16	30	201	268	443	6983.55	633	401	247	73
2018	16	29	201	268	440	6964.88	646	362	218	76
2019	16	29	201	268	452	6984.98	673	943	261	106
2020[a]	16	24	169	225.33	467	5866.05	458	789	231	88
2021	16	29	201	268	494	6955.25	674	973	327	140
2022	16	29	201	268	476	6969.83	657	887	295	93
2023	17	31	213	284	502	7388.90	666	919	270	89

HIA: head injury assessment; NRL: National Rugby League.
[a] Season curtailed by COVID19 epidemic.
[b] Including regular rounds, play-offs, and grand-final. Teams had 0–3 byes during regular rounds depending on season.
[c] Tackle data obtain from https://www.nrl.com/stats/.

Table 2
Frequency and risk of recurrent outcome events.

Number of events	Head impacts		HIAs		Concussions	
	n/892 players	%	n/892 players	%	n/892 players	%
0	208	23.3	338	37.9	539	60.4
1	99	11.1	177	19.8	190	21.3
2	88	9.9	115	12.9	84	9.4
3	56	6.3	76	8.5	39	4.4
4	51	5.7	58	6.5	22	2.5
5	42	4.8	35	3.9	9	1.0
6	39	4.4	27	3.0	6	0.7
7	40	4.5	18	2.0	3	0.3
8	36	4.0	6	0.7	–	–
9	27	23.0	13	1.5	–	–
10	25	2.8	11	1.2	–	–
11	28	3.1	5	0.6	–	–
12	24	2.7	3	0.3	–	–
13	16	1.8	1	0.1	–	–
14	12	1.4	3	0.3	–	–
15	21	2.4	2	0.2	–	–
16	11	1.2	2	0.2	–	–
17	7	0.8	1	0.1	–	–
18	8	0.9	1	0.1	–	–
19	6	0.7	–	–	–	–
20	8	0.9	–	–	–	–
>20	40	4.5	–	–	–	–

Note. %: percentage; HIAs: head injury assessments; n: number.

commonly at the end of a season). Each case was coded by at least one of three main reviewers, with video signs coded independently by 2 raters. Adequate intra- and inter-rater reliability for the video signs of potential concussion in the SCRIMMAGE database for the three main coders has been previously reported. The outcome of in-game HIAs, and concussion diagnoses were provided by the NRL and were added to the database at the conclusion of each season.

Data linkage between SCRIMMAGE head impact cases and NRL records was conducted deterministically using an electronic matching algorithm, based on player name, team, position, and match details shared between the NRL and SCRIMMAGE datasets. All matches were subsequently re-checked manually. In rare cases where there could be any uncertainty over data linkage due to non-unique names (<0.5%) the source video footage of the head impact event was re-reviewed to confirm correct matching.

2.4. Analysis

The studied outcomes were head impacts, HIAs, and concussions identified through the NRL concussion management system. Player exposure was determined by any match participation, athletic exposures (i.e., number of games participated in), and total duration of game time in hours.

The analysis proceeded in four stages. Firstly, the sample was characterised using descriptive statistics. Secondly, risk was calculated for each outcome cumulatively for the study period overall, for each individual season, and the average across seasons. Thirdly, the incidence rate for each outcome was determined per 1000 player-match hours, overall and across each season. Fourthly, incidence rates were re-calculated per 100 athletic exposures.

Risks were calculated using the number of players sustaining an outcome once or more as the numerator, and the total number of players participating in matches, regardless of number or duration, as the denominator. Incidence rates were modelled using Poisson regression with the natural logarithm of exposure time entered as an offset term. Seasonal variations in incidence rates were examined using a joint Wald test. When the overall test was significant, post-hoc pairwise season comparisons were conducted using Bonferroni-adjusted p-values. Analyses were implemented in Stata Statistical Software: Release 19 (StataCorp. 2023, College Station, TX: StataCorp LLC) using the *poisson* command with the *exposure* option, followed by *testparm*, *margins*, and *pwcompare*. 95% confidence intervals were calculated using cluster-robust standard errors to account for overdispersion and within-player correlation arising from recurrent outcomes.

A precision-based sample size calculation was performed using standard formulas for estimation of a crude incidence rate. A desired 95% confidence interval precision of at least ± 1, with an assumed concussion incidence rate of 16 per 1000 player-hours based on previous data, would require 27,318 h of person time at risk. Given 201 matches per season, each lasting 1.33 h, with 26 players participating at any one time, would result in 6968 h of person time at risk per season. The required sample size would therefore be easily achieved by the seven-season duration of the study.

2.5. Ethics and funding

The study was endorsed by the Rugby League Research Committee and approved by the Institutional Human Ethics Committee (Ref No. H-2012-0344). In accordance with the NRL and Rugby League Players Association (RLPA) Collective Bargaining Agreement, all athletes consented a priori for use of injury data in Rugby League Research Committee (RLRC)-endorsed research. This study was unfunded.

3. Results

During the seven studied seasons, between 2017 and 2023, there were 1387 games, with a total of 1849.33 h of gameplay. Overall, 892 individual players participated in at least one NRL game (median 44 games, interquartile range 14–85.5, range 1–171). Individual cumulative match time varied from 1 to 13,655 min (median 2271.5, IQR 502.5–5091.0), resulting in a total of 48,113.45 exposure hours.

Table 3
Seasonal risk of a player sustaining a head impact, HIA and concussion.[a]

Season	Head impacts			HIAs			Concussions		
	n/N	Point estimate	95% CI	n/N	Point estimate	95% CI	n/N	Point estimate	95% CI
2017	218/443	49.2%	44.6–53.8%	164/443	37.0%	32.6–41.6%	63/443	14.2%	11.2–17.8%
2018	207/440	47.0%	42.4–51.7%	148/440	33.6%	29.4–38.2%	72/440	16.4%	13.2–20.1%
2019	313/452	69.3%	64.8–73.3%	163/452	36.1%	31.8–40.6%	94/452	20.8%	17.3–24.8%
2020	310/467	66.4%	62.0–70.5%	161/467	34.5%	30.2–39.0%	76/467	16.3%	13.19–19.9%
2021	345/494	69.8%	65.6–73.7%	218/494	44.1%	39.7–48.6%	121/494	24.4%	20.8–28.4%
2022	321/477	67.3%	62.9–71.5%	187/477	39.2%	34.8–43.7%	81/477	16.7%	13.6–20.3%
2023	337/502	67.1%	62.8–71.2%	178/502	35.3%	31.1–39.6%	77/502	15.1%	12.2–18.5%
Average seasonal risk	2051/3275	62.6%	60.9–64.3%	1219/3275	37.2%	35.6–38.9%	584/3275	17.8%	16.5–19.2%
Overall risk[b]	684/892	76.7%	73.8-79.3%	554/892	62.1%	58.8–65.3%	353/892	39.6%	36.4–42.8%

Note. %: percentage; CI: confidence interval; HIAs: head injury assessments; n: number; N: total number.

[a] The number of players sustaining the outcome of interest (i.e., ≥1 outcomes, n) is the numerator and the total number of players participating in matches, regardless of number or duration, is the denominator (N).

[b] Numerator is cumulative number of players sustaining the outcome of interest (i.e., ≥1 outcomes); denominator is total number of players.

Table 4
Incidence rates (per 1000 player-match hours) for head impacts, HIAs, and concussions across 2017 to 2023 NRL seasons.

Season	Head impacts			HIAs			Concussions		
	Point estimate	95% CI		Point estimate	95% CI		Point estimate	95% CI	
Overall	*109.62*	*103.47*	*116.13*	*38.43*	*35.55*	*41.55*	*13.80*	*12.52*	*15.21*
2017	57.42	50.54	65.24	35.37	30.52	40.98	10.45	8.18	13.35
2018	51.98	45.57	59.28	31.30	26.67	36.73	10.91	8.75	13.61
2019	135.00	123.35	147.76	37.37	32.21	43.35	15.18	12.59	18.30
2020	134.50	122.56	147.61	39.38	34.05	45.54	15.00	12.04	18.70
2021	139.89	128.99	151.73	47.01	41.47	53.30	20.13	16.75	23.51
2022	127.26	115.73	139.94	42.33	36.90	48.55	13.34	10.77	16.53
2023	124.38	113.88	135.84	36.54	31.55	42.32	12.05	9.67	15.00

Note. %: percentage; CI: confidence interval; HIAs: head injury assessments; n: number; NRL: National Rugby League.

Table 1 summarises exposure time and outcome events. During the study period a total of 5274 head impacts were detected in 684 players (n = 892, risk 76.7%) resulting in 1849 HIAs (in 554 players, n = 892, risk 62.1%) and 665 diagnosed concussions (in 353 players, n = 892, risk 39.6%). Recurrent events are detailed in Table 2. Recurrent events were common with players sustaining a median of three head impacts (IQR 1–9, range 0–56), undergoing a median of one HIA (IQR 0–3, range 0–19), and 18.3% of players being diagnosed with two or more concussions (163/892, median of 0 concussions, IQR 0–1, range 0–7). The average risk per season for a NRL player of sustaining any head impact, HIA, or concussion was 62.6% (95% CI 60.9–64.3%), 37.2% (95% CI 35.6–38.9%), and 17.8% (95% CI 16.5–19.2%), respectively. Outcome risks, stratified by season, are detailed in Table 3.

Across all seasons, the incidence rate for head impacts per 1000 player-match hours was 109.62 (95% CI 103.47–116.13). Incidence varied significantly ($p < 0.01$) with a marked step-increase in rate between the 2017–2018 and 2019–2023 seasons. Overall HIA incidence rate per 1000 player-match hours was 38.43 (95% CI 35.55–41.55). Incidence was relatively stable across seasons, ranging from 31.30 to 47.01 in 2018 and 2021 respectively, with a statistically significant higher rate observed for 2018 vs 2021 only ($p < 0.01$). The overall incidence rate for concussion per 1000 player-match hours was 13.80 (95% 13.33–16.11). There was a notable increased incidence of 20.13 per 1000 player-match hours in the 2021 season, which was significantly higher than the 2017, 2018, 2022, and 2023 seasons (which ranged between 10.45 and 13.34, $p < 0.01$). Table 4 and Fig. 1 detail the incidence rates per 1000 player-match hours for head impacts, HIAs, and concussions.

On average, players sustained a head impact once every 9.15 games (incidence rate of 10.92 per 100 athletic exposures, 95% CI 10.34–11.54), an HIA once every 26.12 games (incidence rate of 3.83 per 100 athletic exposures, 95% CI 3.57–4.11) and a concussion once every 72.46 games (incidence rate of 1.38 per 100 athletic exposures, 95% CI 1.25–1.51).

4. Discussion

Professional collision sports leagues around the world have increasingly developed in-game surveillance systems to improve the identification of potential concussion.[15] In this study, head impact, HIA, and concussion events are described across seven seasons of the National Rugby League. The average risk for head impacts, HIAs, and concussion per player was 62.6% (95% CI 60.9–64.3%), 37.2% (95% CI 35.6–38.9%), and 17.8% (95% CI 16.5–19.2%) each season, respectively. Recurrent events were common over the studied seven seasons, with players sustaining a median of three head impacts, a median of one HIA, and 18.3% of players being diagnosed with more than one concussion over the study period. Incidence rates for head impacts, HIAs, and concussions were 109.6, 38.4 and 13.8 per 1000 player-match hours respectively. A difference in the incidence rate of head impacts was observed between the 2017–2018 and 2019–2023 seasons. The incidence rate of HIAs and concussions was significantly increased in the 2021 season.

The increase in head impacts observed from 2019 onwards may be explained by systematic changes in the NRL concussion management system at this time, with increased scrutiny of match play likely resulting in the identification of more subtle head impacts. This position would be supported by the relative stability in the rate of HIAs, with additionally detected, lower energy, head impacts not meeting the Category 1 or Category 2 HIA thresholds. Concussion and HIA rates were notably higher in 2021 compared to earlier and later years. Although the rate of head impacts was similar this season, there was an increase in HIAs, suggesting a possible lower threshold for medical assessment and subsequent concussion diagnosis. Reasons for this difference are likely multifactorial, including COVID-pandemic related factors e.g., change in risk thresholds, increased media interest in concussion, and possibly introduction of the NRL injury surveillance bunker. This also coincided with a return to one referee, from the two-referee system, and a change in rule from round 3 onwards (the 6-again rule), that kept the ball in play longer and quickened up game play.

To the best of our knowledge, SCRIMMAGE is the largest and most comprehensive rugby league video analysis database. Compared to previous professional men's rugby league research from smaller samples conducted during a different era (i.e., different definition of concussion and less match-day injury surveillance infrastructure and protocols), the current concussion incidence is considerably higher: 13.8 compared to 1.6,[16] 8.9,[17] and 9.8,[18] but relatively similar to other studies (15.5[3] and 14.8[5] concussions per 1000 player hours), and lower than the reported 28.3[6] incidence from a single professional rugby league club across 15 consecutive NRL seasons.

As a fast-paced, physical sport, rugby league inherently carries a risk of head injury. These data should provide helpful information to players and administrators on the rates of head impacts and concussion from participating in the NRL. Objective risk estimates from this study could inform playing choices and will provide a comparative baseline for any future rule changes or interventions relating to concussion. Ultimately, it is important to quantify this issue transparently, to appropriately address player safety, whilst considering the integrity of the sport.

As a study at the elite club level, these findings should be generalisable to other adult male professional rugby league settings, including international competitions. Concussion rates in professional sport have been previously shown to vary between different sexes, so any extrapolation to National Women's Rugby League should be made cautiously. Similarly, the results may not be generalisable to amateur or age-grade rugby league.

Although this is the first comprehensive study in the NRL, concussion incidence has been examined previously in other rugby league settings and has been investigated in rugby union and other collision sports. Overall, concussion incidence appears to be lower in the NRL. Eastwood and colleagues observed a slightly higher concussion rate of 15.5 per 1000-player match hours in the European Super League over a similar study period.[3] Injury surveillance reports (2016–2022) from the English Rugby Union demonstrate significantly higher concussion incidence rates between 18.2 and 22.2 over this period. A systematic

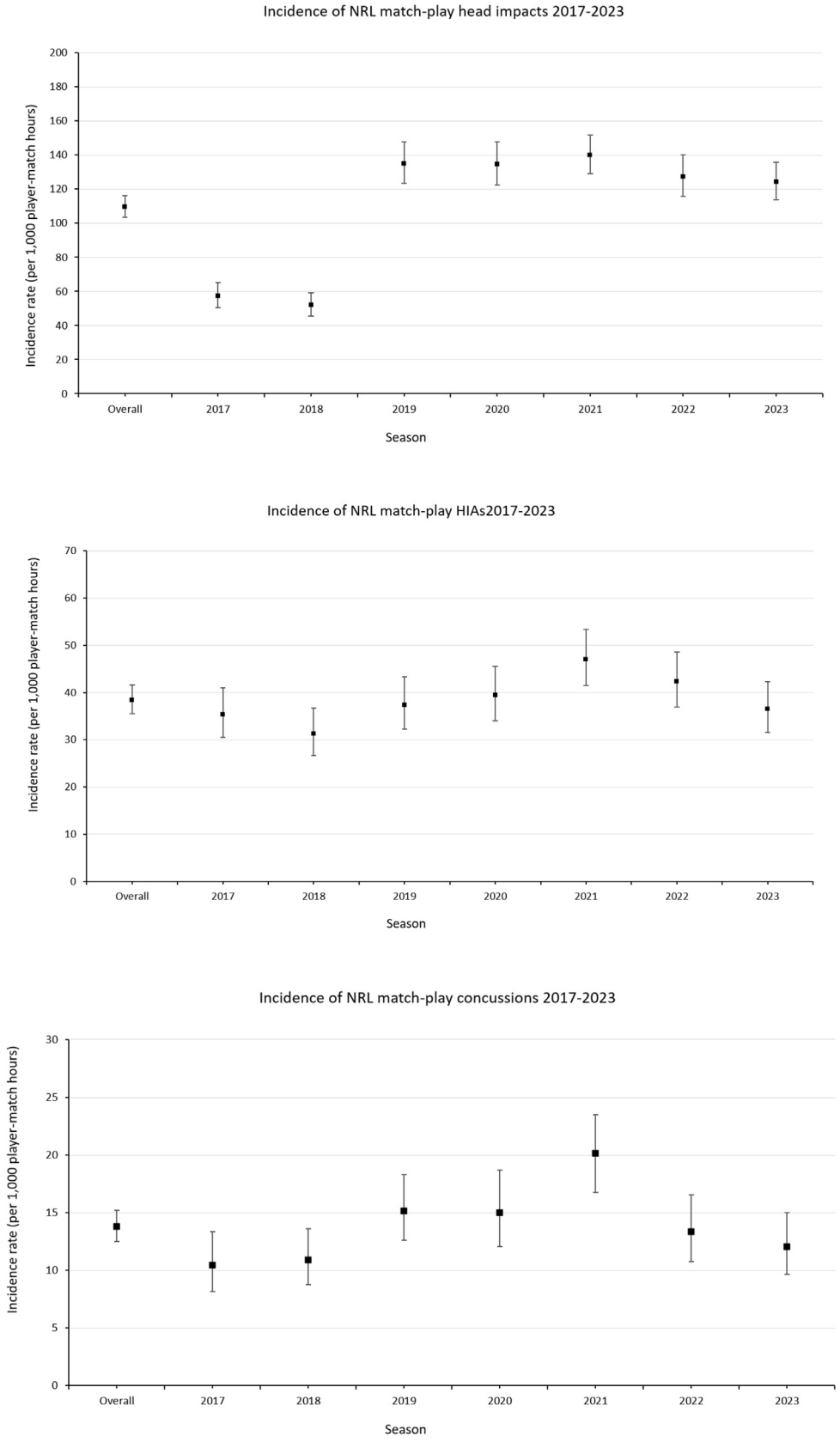


Fig. 1. Incidence rates (per 1000 player-match hours) for head impacts, HIAs, and concussions across 2017 to 2023 NRL seasons.

review by McNeel and colleagues[15] in Australian Rules Football found incidence rates of between 2.24 and 17.63 per 1000-player match hours at the elite level. NRL, Rugby Union, and Australian Rules Football have similar comprehensive concussion management systems, including head impact detection and standardised medical assessment protocols, suggesting that incidence rates should be comparable.

This study has several strengths, including accurate outcome and exposure measurement through the SCRIMMAGE database, NRL concussion management system, and official NRL match data. However, there are some limitations. Training outcomes and exposure were not studied, which prevents a holistic overview of concussion incidence and risk.[16] Head impact detection was reliant on visual or video detection, which could potentially have missed some incidents e.g., obscured in multi-player tackles. Instrumented mouth guards have been recently used in rugby league and could provide additional information in the future on forces applied to the head, including cumulative loads.[17] Finally, despite standardised medical assessment using the gold-standard SCAT tool, concussion is an inherently subjective diagnosis.[18]

5. Conclusion

In conclusion, head impacts, HIAs, and concussions were common injuries in NRL, but may have relatively lower rates than in other professional rugby league competitions, Rugby Union or Australian Rules Football. This burden of injury justifies the comprehensive NRL concussion management system and suggests ongoing efforts to mitigate the risk of head impacts, balanced against match-play considerations, could be beneficial. Further research could usefully examine head impact risk factors for concussion, such as tackle characteristics, and investigate injury risk in training, amateur, and female settings.

CRediT authorship contribution statement

GWF conceptualised the study methodology, conducted the formal analysis of the data, wrote the original draft, and reviewed and edited the paper.

SF is the custodian of the clinical data, managed the oversight of the data collection, and reviewed and edited the paper.

AJG is the principal investigator of the SCRIMMAGE research program. AJG conceptualised the study methodology, collected the data, managed and curated the database, liaised with the clinical data custodian, wrote the original draft, and reviewed and edited the paper.

Confirmation of ethical compliance

The research design was approved by the University of Newcastle Human Ethics Committee (H-2012-0344). This work was conducted in accordance with the Declaration of Helsinki and the National Statement on the ethical conduct of human research and in line with national privacy laws.

Participants gave informed consent to participate in the study before taking part.

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Declaration of interest statement

GWF has previously received travel expenses from World Rugby for attending research meetings.

SF is the Chief Medical Officer of the National Rugby League (NRL).

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Data availability

In accordance with the NRL and Rugby League Players Association (RLPA) Collective Bargaining Agreement, study data are not available to share. Full analysis code is available on request. Official NRL game records, providing player exposure data, are freely available at https://www.nrl.com/stats [accessed 22nd May 2026].

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