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# Head injury assessment in youth men's rugby league players: An evaluation of game play characteristics and video review of potential concussion signs



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## ABSTRACT

**Background:** Rugby league is a popular collision sport among Australian adolescent and young adult men. Concussion is one of the more common injuries in rugby league. Few studies have examined concussion in youth rugby league. To examine medically diagnosed concussions from a single season within two elite-level pathway rugby league competitions by evaluating game play risk factors and conducting a video review of potential concussion signs.

**Methods:** All players involved in the Queensland Rugby League's (QRL) under 18 years and under 20 years age group competitions during the 2019 season were included in this study. Data included all head injury assessments (HIAs) identified in real-time through the QRL injury surveillance system for these two QRL age group competitions. The purpose of this study was to (i) report the rates of HIAs and medically diagnosed concussions; (ii) examine video signs of potential concussion; (iii) review game play risk factors related to HIAs and concussions; and (iv) determine the number of days until a concussed player returned to match play and the number of subsequent games missed by concussed players.

**Results:** There were 86 HIAs and 30 medically diagnosed concussions from the two competitions. The concussion incidence was 2.93 per 1000 player match hours in the under 18-year age group and 5.75 per 1000 player match hours in the under 20-year age group. Slow to stand was the most commonly observed video sign (78.6%; 22/28 concussions). Most concussed players (91%, 21/23) missed at least one subsequent game ( $M = 1.4$ ,  $SD = 1.7$ , range = 0–7 games), with the average days to return-to-play being 15.7 ( $SD = 7.0$ , range = 7–41 days).

**Conclusions:** In elite-level pathway rugby league, the incidences of HIAs and medically diagnosed concussions were higher in the under 20 age group than the under 18 age group. Both age groups had lower incidences of HIAs and concussions than professional adult rugby league players. Return-to-play following concussion was similar across the two age groups and differed considerably compared to the elite level, with a longer time before return to play for the younger elite level development pathway players.

**Abbreviations:** HIA, head injury assessment; IRR, inter-rater reliability; LOC, loss of consciousness; NRL, National Rugby League; QLD, Queensland; QRL, Queensland Rugby League.

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### Key Points

- This study is the first to integrate Head Injury Assessment surveillance, video review, and return to play data in elite-level pathway rugby league players.
- The under 20 and under 18 male age groups had lower incidences of HIAs and concussions than professional male adult rugby league players but had a longer time before returning to play than professional adult rugby league players.
- The under 20 and under 18 male age group players removed from play for a HIA displayed multiple video signs on retrospective video whether they were medically diagnosed with concussion or returned to play and took an average of 15.7 days to return to play following a concussion diagnosis.

## 1. Introduction

Injury surveillance is important for injury prevention [1]. Understanding injury incidence, risk factors [2], and visual signs of injury [3] can help with effective management, especially in concussion [1]. At the professional level, leagues have established robust, real-time systems for identifying athletes with a suspected concussion through sideline video [4]. This often includes trained spotters placed in strategic locations around the stadium and trained medical staff in centralised locations to identify and review head impact events via video footage of multiple camera angles [5]. The Head Injury Assessment (HIA) process allows medical staff to evaluate athletes for a suspected concussion, and if the player is evaluated and medically cleared to return to play, the removal and return of the player does not impact on the limited number of game-related interchanges a team is permitted each game [6]. In rugby league, the HIA includes a predetermined protocol for the in-game identification and management of a suspected concussion. This protocol codifies concussion signs and symptoms that either mandate the immediate and permanent removal of an athlete (referred to in the National Rugby League [NRL] as Category I signs and symptoms) or trigger a further medical evaluation for concussion (referred to in the NRL as Category II signs and symptoms) [5,7].

The elite level development pathway for Australian rugby league players starts with the under 16 age group and leads to increasing participation in higher levels of competition over subsequent years in state-based competitions [8]. There are concerns that youth athletes may be more likely to experience a concussion [9–11] and take longer to recover than adults [12–15]. While the incidence of HIAs has been evaluated in the elite level under 20s national rugby league competition in Australia [16] and the incidence of concussion has been reported in several groups (e.g., Australian 17–18 year old players [17], English academy teams [18,19], New Zealand under 16s and under 18s players [20]), the comprehensive evaluation of game play risk factors and video review of potential concussion signs has not been conducted in sub-elite rugby league players. In addition, the concussion surveillance process has been comprehensively evaluated at the elite level [5,6,19,21–28], but limited research has been conducted examining the concussion surveillance process in youth rugby league players [16,18–20]. As such, the purpose of this study was to (i) report the rates of HIAs and medically diagnosed concussions; (ii) examine video signs of potential concussion; (iii) review game play risk factors related to HIAs and concussions; and (iv) determine the number of days until a concussed player returned to match play and the number of subsequent games missed by concussed players.

## 2. Methods

### 2.1. Participants

This study evaluated match footage from the 2019 seasons for the under 18 and under 20 age groups. These competitions are Queensland

Rugby League's (QRL) highest level of club competitions for young males aged 17–20 years old. The QRL is the governing body of rugby league in the state of Queensland, Australia. The under 18s competition is comprised of fourteen teams, competing over 6 rounds, with a two-week finals system between four qualifying teams. A total of 45 games were played during the under 18s season. The under 20s competition is comprised of fourteen teams, competing over 20 rounds, with a four-week finals system between eight qualifying teams. A total of 149 games were played during the 2019 under 20s season. A total of 194 games were played across both the under 18s and under 20s competitions. Games in both age groups are played in two 35-min halves, for a total game duration of 70 min. The players gave consent to the Rugby League Players Association and the QRL to have their deidentified data used in research endorsed by the QRL Research Committee. This study was approved by the governing institution human ethics committee and endorsed by the QRL Research committee.

### 2.2. Procedures

All players who were removed from play for a HIA were identified by the QRL's medical staff and via the sideline injury surveillance team (sports trainers). The legal height of a tackle during the 2019 QRL season was from the shoulders and lower. Contact made to a ball carrier above the shoulders should result in a penalty to the ball carrier's team. An HIA was identified as a head impact event that necessitated the player being removed from the match (either the temporarily or permanently) due to a suspected concussion. Permanent removal from the game occurs when any of the signs of concussion are identified by the surveillance teams. This is completed in accordance with the QRL concussion recognition and management protocols [29]. In cases where there is no sign of concussion necessitating permanent removal, the player receives an off-field medical evaluation which guides return to play decisions. All HIAs, involving temporary or permanent removals, are included in this study. The QRL also identified players who were medically diagnosed with a concussion by the match day medical staff or the club medical staff.

### 2.3. Retrospective video review and coding

Video analyses of all HIAs were conducted using the STATS Edge™ program, with full access to video provided by the QRL. Unlike the broadcasted games in the QRL first grade competition, which include multiple camera angles during broadcasted games, only one camera angle was accessible for video analyses in the current study. The video coder was able to review the event as many times as required to code the variables accurately. This included the ability to pause the video and to play the footage in slow motion. The video analysis was conducted by a single author (MAL, a former NRL rugby league player), utilising a coding matrix including 46 variables for each HIA incident.

Some of the key coding variables included player body positions for both the tackler and ball carrier at contact, tackle height, the tackler's

head position, and the ball carrier's evasion strategy [30]. A total of seven video signs of potential concussion were considered in this study. The video signs included: (i) no protective action; (ii) balance disturbance; (iii) seizure; (iv) tonic posturing; (v) dazed, blank look, or vacant stare; (vi) loss of responsiveness; and (vii) slow to stand. The video signs of concussion that were used in this study have been previously described and defined [3].

#### 2.4. Video coding training

The main video reviewer/coder was trained on the definition of each variable and how to apply the definition to cases from a separate dataset of HIA cases from the Queensland (QLD) Cup, by the first author. The first author has extensive experience coding video of tackle events, HIAs, and medically diagnosed concussions. The training process has been described elsewhere [31].

#### 2.5. Return to play

For athletes who were concussed, return to play data was determined by reviewing the publicly available team sheets on the QRL website for the under 18 and under 20 age group competitions (<https://www.qrl.com.au/draw/?competition=155&round=1&season=2019>). The days to return to play were calculated as the time (in days) between the date of the injury and the date that the concussed player returned to match play. The games missed was calculated as all games played by the concussed player's club during the time he was not recorded as having played on the team sheet. Days to clinical recovery and days to medical clearance to return to play were not available.

#### 2.6. Data analysis

The HIA and concussion incidence for each competition (under 18s and under 20s) were calculated by dividing the number of events by the total number of matches multiplied by the number of players, multiplied by the game duration (i.e., 70 min) and then multiplied by 1000 to report the incidence in events per 1000 player match hours [32]. The number of HIAs and concussions per game were calculated by dividing the number of HIAs or concussions by the number of games played in the under 18 (n = 45) and under 20 (n = 149) age group competitions.

### 3. Results

During the 2019 QRL's under 18s and under 20s seasons, there were 86 total HIAs, 30 of which resulted in a medically diagnosed concussion by the match day medical staff or the club medical staff. There were two players that were medically diagnosed with concussion following the match, for which there was no identified head impact event that caused the concussion (i.e., the player was not removed from play for a HIA during the match); thus, there was no video to be reviewed for these two concussions, leaving the total sample of 84 HIAs with useable video footage. Overall, one-third of players (28/84, 33.3%) who were removed from play for a HIA were diagnosed with a concussion. The combined incidence rate across both elite level development pathway age groups was 14.61 HIAs per 1000 player match hours and the concussion incidence rate was 5.10 concussions per 1000 player match hours. Across both age groups, there was one HIA every 2.3 games and one concussion every 6.5 games.

There were 7 HIAs and 4 medically diagnosed concussions in the under 18s groups. For the under 18s, the HIA incidence rate was 5.13 HIAs per 1000 player match hours and the concussion incidence rate 2.93 concussions per 1000 player match hours. There was one HIA every 6.4 games and one concussion every 11.3 games for the under 18s players. For the under 20s, there were 79 HIAs and 26 medically diagnosed concussions. The HIA incidence rate was 17.48 HIAs per 1000 player match hours and the concussion incidence rate was 5.75 concussions per

1000 player match hours for the under 20s. In this age group, there was one HIA every 1.9 games and one concussion every 5.7 games.

#### 3.1. Game-play characteristics

Game-play characteristics for the cases of medically diagnosed concussion with video footage (n = 28) and for the non-concussed players who underwent HIAs (n = 56) are shown in Table 1 and Table 2. Of the 84 HIAs, 77 (91.6%) occurred in a tackle event. The remaining 7 HIAs (8.4%) were observed in game play incidents that did not involve a tackle contest, such as through aerial contests or off-the-ball collisions. Of the 28 medically diagnosed concussions with video footage, 26 (92.9%) occurred in a tackle event. Of the HIA events, 27 were sustained by tacklers (48.2%) and 24 were sustained by ball carriers (42.9%). Of the medically diagnosed concussions, 15 were sustained by tacklers (53.6%) and 11 were sustained by ball carriers (39.3%). There were 5 (8.9%) HIAs and 2 (7.1%) concussions where the player was neither a tackler nor a ball carrier. Half (50%, 10/20) of players who were removed from play for a HIA in the second quarter of the game (i.e., 21–40 min) were diagnosed with a concussion, and 41.7% (5/12) of players who were removed from play for a HIA in the fourth quarter of the game (i.e., 61–80 min) were diagnosed with a concussion (see Table 1). Half (50%, 11/22) of players who were removed from play for a HIA where the incident occurred in the midfield attacking area of the field were diagnosed with a concussion (see Table 1). For the tackle number in the set, 47.1% (8/17) of players who were removed from play for a HIA on the third tackle and 42.1% (8/19) of players who were removed from play for a HIA on the fourth tackle were diagnosed with a concussion (see Table 1).

The contact mechanisms for the cases of medically diagnosed concussion with video footage (n = 28), HIAs (n = 56), and total overall sample (n = 84) are shown in Table 2. Head-to-head and head-to-shoulder contact were the most common mechanisms for both the players diagnosed with concussion (28.6% and 21.4%, respectively) and the players who underwent a HIA but were not diagnosed with a concussion (33.9% and 25.0%, respectively). There were 21 players who were removed for a HIA following a bent at the waist tackle, and of those 8 (38.1%) were diagnosed with a concussion (see Table 2). There were 53 players who were removed for a HIA following an upright tackle, and of those 17 (32.1%) were diagnosed with a concussion (see Table 2). There were 2/28 (7.1%) of the medically diagnosed concussion cases and 4/56 (7.1%) HIAs that were a result of foul play (6/84 7.1% of cases overall).

For individual case characteristics of players who were medically diagnosed with a concussion see Table 3. For individual case characteristics of players who were removed from play for a HIA but who were not medically diagnosed with concussion see Table 4.

#### 3.2. Video signs of possible concussion

Video signs of possible concussion are presented in Table 5. Lying motionless was observed in 21.4% (6/28) of concussions and 35.7% (20/56) of players who were removed from play for a HIA but who were not diagnosed with a concussion. No protective action was observed in 28.6% (8/28) of concussions and 35.7% (20/56) of players who were removed from play for a HIA but who were not diagnosed with a concussion. There were no seizures or tonic posturing observed in any cases. Balance disturbance was observed in 67.9% (19/28) of concussions and 75.0% (42/56) of players who were removed from play for a HIA but who were not diagnosed with a concussion. A dazed, blank, or vacant stare was observed in 25.0% (7/28) of concussions.

There were no observable video signs of concussion in 4/28 (14.3%) concussions and 2/56 (3.6%) players who were removed from play for a HIA but who were not diagnosed with a concussion. In 7/28 (25.0%) concussions there were four or more (out of seven) video signs of potential concussion. Nearly half (25/56; 44.6%) of players removed for a HIA but not diagnosed with a concussion had four or more (out of seven) video signs of potential concussion.

**Table 1**

Frequency of various game play characteristics involving medically diagnosed concussions and players removed from play for a head injury assessment but who were not diagnosed with a concussion.

Game Play Characteristic	Variable	Concussion (n = 28)		HIA (non-concussed) (n = 56)		Total (n = 84)	
		N	%	N	%	N	%
Tackle Event	Yes	26	92.9	51	91.1	77	91.7
	No	2	7.1	5	8.9	7	8.3
Tackler vs Ball Carrier	Tackler	15	53.6	27	48.2	42	50.0
	Ball Carrier	11	39.3	24	42.9	35	41.7
	Neither	2	7.1	5	8.9	7	8.3
Playing Position	Forward	21	75.0	38	67.9	59	70.2
	Back	7	25.0	18	32.1	25	29.8
Tackle Height	Head	6	21.4	13	23.2	19	22.6
	Upper Torso	17	60.7	29	51.8	46	54.8
	Mid Torso	3	10.7	5	8.9	8	9.5
	Lower Torso	2	7.1	3	5.4	5	6.0
	Upper Leg	0	0	2	3.6	2	2.4
	Lower Leg	0	0	4	7.1	4	4.8
Number of Tacklers	1	5	17.9	8	14.3	13	15.5
	2	12	42.9	24	42.9	36	42.9
Involved in the Tackle	3	9	32.1	18	32.1	27	32.1
	4	0	0	1	1.8	1	1.2
	Not a tackle	2	7.1	5	8.9	7	8.3
	0	0	0	4	7.1	4	4.8
Tackle Number in the Set	1	3	10.7	9	16.1	12	14.3
	2	5	17.9	11	19.6	16	19.0
	3	8	28.6	9	16.1	17	20.2
	4	8	28.6	11	19.6	19	22.6
	5	4	14.3	8	14.3	12	14.3
	6	0	0	4	7.1	4	4.8
	Field Location	Middle Corridor	23	82.1	40	71.4	63
	Side Corridor	5	17.9	16	28.6	21	25.0
	DQ	1	3.6	9	16.1	10	11.9
	MDQ	11	39.3	18	32.1	29	34.5
	MAQ	11	39.3	11	19.6	22	26.2
	AQ	5	17.9	18	32.1	23	27.4
Time in Game	First Half	14	50.0	25	44.6	39	46.4
	Second Half	14	50.0	31	55.4	45	53.6
	1Q (0–20mins)	4	14.3	15	26.8	19	22.6
	2Q (21–40mins)	10	35.7	10	17.9	20	23.8
	3Q (41–60mins)	9	32.1	24	42.8	33	39.3
	4Q (61–80mins)	5	17.9	7	12.5	12	14.3
Foul Play	Yes	2	7.1	4	7.1	6	7.1
	No	26	92.9	52	92.9	78	92.9

Note. 1Q: first quarter of the game; 2Q: second quarter of the game; 3Q: third quarter of the game; 4Q: fourth quarter of the game; AQ: attacking quarter; DQ: defensive quarter; MAQ: midfield attacking quarter; MDQ: midfield defensive quarter; n: number; vs: versus.

**Table 2**

Tackle contact mechanism and tackler body position stratified by medically diagnosed concussion cases and players removed from play for a head injury assessment but who were not diagnosed with a concussion.

Characteristic	Concussions (n = 28)		Head Injury Assessments, No Concussion (n = 56)		Head Injury Assessments Total (n = 84)	
	f	%	f	%	f	%
Mechanism of Head Contact						
Head-to-Head	8	28.6	19	33.9	27	32.1
Shoulder	6	21.4	14	25.0	20	23.8
Knee	2	7.1	4	7.1	6	7.1
Elbow	1	3.6	0	0.0	1	1.2
Forearm	2	7.1	1	1.8	3	3.6
Hip	3	10.7	5	8.9	8	9.5
Playing Surface	2	7.1	5	8.9	7	8.3
Ball	1	3.6	0	0.0	1	1.2
Hand	0	0.0	2	3.6	2	2.4
Foot	0	0.0	2	3.6	2	2.4
Back	0	0.0	1	1.8	1	1.2
Unknown Contact Type	3	10.7	2	3.6	5	6.0
Tackler Position						
Upright	17	60.7	36	64.3	53	63.1
Bent-at-Waist	8	28.6	13	23.2	21	25.0
Slipping/Falling	2	7.1	2	3.6	4	4.8
Flopping/BC on the Ground	1	3.6	1	1.8	2	2.4
Diving	0	0.0	3	8.3	3	3.6
Leaping/Jumping	0	0.0	1	1.8	1	1.2

Note. f: frequency; %: percentage; BC = ball carrier.

**Table 3**  
Coded variables for players medically diagnosed with concussion (n = 30).

ID No.	Video Signs						Days to return To play	Games Missed	Ball Carrier v Tackler	Playing Position	Tackler Body Position	Ball Carrier Body Position	Tackler Height	Head Contact From	Foul Play	Tackle No. in Set
	No Protective Action	Balance Disturbance	Dazed or BL or VS	Loss of Responsiveness	Slow To Stand	Total Video Signs										
1	0	0	0	0	0	0	14	1	BC	Bk	BAW	BAW	UT	Unknown	No	3
2	1	1	1	1	1	5	14	1	BC	Fwd	Upright	Upright	UT	Head	No	3
3	0	1	1	0	1	3	41	4	T	Fwd	BAW	Fall/Dive	UT	Head	No	2
4	0	1	1	0	1	3		6	BC	Bk	Upright	Upright	Head	Shoulder	Yes	4
5	0	1	0	0	1	2	15	1	T	Fwd	Upright	Upright	UT	Head	No	1
6	1	1	1	1	1	5	15	1	BC	Fwd	Slip/Fall	Fall/Dive	UT	Knee	No	3
7							14	1								
8	1	1	0	1	1	4	12	1	BC	Fwd	Upright	Upright	Head	Forearm	Yes	5
9	0	1	0	0	1	2	7	0	BC	Bk	Slip/Fall	Fall/Dive	Head	Ground	No	5
10							12	1								
11	0	0	0	0	1	1	15	1	T	Bk	Upright	Upright	UT	Head	No	2
12	0	0	0	0	0	0			T	Fwd	BAW	Upright	UT	Elbow	No	3
13	0	0	0	0	1	1	14	1	BC	Fwd	Upright	Upright	Head	Shoulder	No	4
14	0	0	0	0	1	1	14	1	T	Fwd	BAW	Upright	LT	Thigh	No	4
15	0	0	0	0	0	0	15	1	Neither	Fwd	Upright	Upright	UT	Unknown	No	5
16	0	1	0	0	1	2			T	Fwd	Flop	Fall/Dive	MT	Knee	No	3
17	0	1	0	0	0	1	14	1	T	Bk	Upright	Upright	UT	Head	No	3
18	0	0	0	0	1	1	7	0	BC	Fwd	Upright	Upright	Head	Ground	No	4
19	1	1	0	1	1	4			T	Fwd	BAW	BAW	LT	Hip	No	2
20	1	1	1	0	1	4	13	1	T	Fwd	Upright	Upright	UT	Head	No	4
21	1	1	1	1	1	5	12	1	T	Fwd	BAW	Upright	MT	Hip	No	4
22	0	0	0	0	1	1	27	3	BC	Bk	Upright	Upright	UT	Head	No	2
23	1	1	0	0	1	3	22	2	T	Fwd	Upright	Upright	UT	Shoulder	No	5
24	0	1	0	0	1	2	15	1	BC	Fwd	Upright	Upright	UT	Shoulder	No	1
25	0	1	0	0	1	2	13	1	BC	Fwd	Upright	Upright	UT	Unknown	No	1
26	0	1	0	0	1	2	21	2	T	Bk	BAW	Upright	UT	Shoulder	No	4
27	0	1	0	0	0	1		7	T	Fwd	Upright	Upright	UT	Shoulder	No	3
28	1	1	1	1	1	5	14	1	T	Fwd	Upright	Upright	UT	Head	No	2
29	0	0	0	0	0	0			T	Fwd	BAW	Upright	MT	Hip	No	4
30	0	1	0	0	1	2		0	Neither	Fwd	Upright	Kicking	Head	Ball	No	4

Note. BAK: bent at knees; BAW: bent at waist; BC: ball carrier; Bk: back; BL: blank look; Fwd: forward; MT: mid trunk; LL: lower leg; LOC: loss of consciousness; LT: lower trunk; NA: not applicable; No.: number; T: tackler; UT: upper trunk; v: versus; VS: vacant stare. \*Two video signs; seizure and tonic posturing, were not observed on retrospective video review of players that were medically diagnosed with a concussion. As such, seizure and tonic posturing have not been included in the video signs in this table.

**Table 4**  
 Coded variables for players removed from play for a head injury assessment but who were not diagnosed with a concussion (n = 56).

ID No.	Video Signs						Ball Carrier v Tackler	Playing Position	Tackler Body Position	Ball Carrier Body Position	Tackler Contact	Head Contact From	Foul Play	Tackle No. in Set
	No Protective Action	Balance Disturbance	Dazed or BL or VS	Loss of Responsiveness	Slow To Stand	Total Video Signs								
1	1	1	1	1	1	5	BC	Fwd	Upright	Upright	Head	Shoulder	No	1
2	0	0	0	0	1	2	T	Bk	BAW	BAW	UL	Hip	No	5
3	1	1	0	0	1	4	BC	Fwd	Upright	Upright	Head	Forearm	Yes	4
4	0	1	0	1	1	3	T	Bk	Upright	Upright	UT	Head	No	5
5	0	0	0	0	1	2	T	Bk	Upright	Upright	UT	Unknown	No	4
6	0	1	1	0	1	4	BC	Fwd	Upright	Upright	UT	Shoulder	No	2
7	0	1	1	0	1	4	T	Fwd	Upright	Upright	UT	Head	No	3
8	1	1	0	1	1	4	T	Bk	Upright	Upright	UT	Shoulder	No	4
9	1	1	0	1	1	4	T	Bk	BAW	Upright	MT	Hip	No	3
10	1	1	1	0	1	5	Neither	Bk	Leap/Jump	Lying on BC	Head	Ground	Yes	0
11	0	1	0	1	1	3	BC	Fwd	Upright	Upright	Head	Hand	Yes	2
12	0	1	0	0	1	2	BC	Bk	Upright	Upright	UT	Head	No	4
13	0	0	0	0	0	0	T	Fwd	BAW	BAW	LT	Hip	No	4
14	1	1	0	1	1	4	BC	Bk	Upright	Upright	UT	Head	No	3
15	0	1	0	0	1	3	T	Fwd	Diving	Upright	UL	Knee	No	4
16	0	0	0	0	1	1	BC	Bk	Flop	Fall/Dive	UT	Knee	No	6
17	0	1	0	1	1	3	T	Bk	BAW	Fall/Dive	Head	Head	No	1
18	0	0	0	0	0	1	T	Fwd	Diving	Upright	LL	Foot	No	2
19	0	1	0	0	1	3	BC	Fwd	Upright	Upright	Head	Shoulder	No	2
20	0	1	0	0	1	3	T	Fwd	Upright	Upright	UT	Shoulder	No	3
21	1	1	1	0	1	5	T	Fwd	Diving	Fall/Dive	LL	Foot	No	0
22	0	0	0	0	0	1	T	Fwd	BAW	Upright	LT	Unknown	No	3
23	1	1	1	1	1	5	T	Fwd	Upright	Upright	UT	Shoulder	No	2
24	1	1	1	1	1	5	Neither	Bk	Upright	BAW	Head	Head	No	0
25	1	1	1	0	1	5	T	Fwd	BAW	Upright	MT	Hip	No	1
26	0	1	0	0	1	3	T	Fwd	Upright	Upright	UT	Head	No	2
27	1	1	0	0	1	3	BC	Fwd	Upright	Upright	UT	Ground	No	4
28	0	1	0	0	1	3	BC	Fwd	Upright	Upright	UT	Shoulder	No	2
29	0	0	0	0	0	0	BC	Fwd	Upright	Upright	UT	Head	No	4
30	1	1	1	0	1	5	BC	Fwd	Upright	Upright	Head	Shoulder	Yes	2
31	1	1	1	1	1	5	BC	Fwd	Upright	Upright	Head	Shoulder	No	1
32	0	1	1	1	1	4	BC	Fwd	Upright	Upright	UT	Shoulder	No	5
33	0	1	1	1	1	4	Neither	Fwd	Upright	BAW	Head	Head	No	0
34	0	1	1	0	1	4	T	Fwd	BAW	Upright	MT	Unknown	No	3
35	1	1	0	0	1	4	BC	Fwd	BAW	Upright	MT	Ground	No	4
36	0	0	0	0	1	2	BC	Fwd	Upright	Upright	UT	Head	No	2
37	0	1	1	1	1	4	T	Fwd	BAW	Fall/Dive	Head	Head	No	1
38	1	1	1	0	1	5	T	Fwd	Upright	Upright	UT	Head	No	1
39	1	1	1	1	1	5	BC	Bk	Upright	Upright	UT	Shoulder	No	5
40	0	1	0	0	1	3	T	Fwd	BAW	Upright	UT	Head	No	2
41	0	0	0	0	1	2	T	Bk	Upright	BAW	UT	Head	No	6
42	0	1	0	0	1	3	T	Fwd	Upright	Upright	UT	Hand	No	3
43	0	1	0	0	1	3	BC	Bk	Upright	BAW	UT	Shoulder	No	1
44	1	1	0	1	1	4	BC	Bk	Upright	Upright	UT	Ground	No	3
45	0	1	1	1	1	4	BC	Bk	Slip/Fall	On Ground	LL	Knee	No	5
46	1	0	0	1	0	1	T	Bk	Upright	Upright	UT	Head	No	1
47	0	0	0	0	1	1	T	Fwd	Upright	Upright	UT	Head	No	2
48	1	1	0	1	1	4	BC	Fwd	Upright	Upright	Head	Shoulder	No	1
49	0	1	1	0	1	4	Neither	Bk	Upright	Upright	Head	Head	No	6
50	0	1	0	1	1	3	BC	Fwd	Upright	Upright	UT	Head	No	5
51	0	1	0	0	1	3	T	Fwd	BAW	BAW	LT	Hip	No	5
52	0	0	0	0	1	2	T	Fwd	BAW	Upright	UT	Shoulder	No	5
53	0	1	0	1	1	3	Neither	Fwd	Slip/Fall	Fall/Dive	LL	Knee	No	6
54	0	0	0	0	0	1	BC	Fwd	Upright	Upright	UT	Head	No	3
55	0	1	0	0	1	3	T	Fwd	BAW	Upright	MT	Back	No	4
56	1	0	0	0	1	3	BC	Fwd	Upright	Upright	UT	Ground	No	4

Note. BAK: bent at knees; BAW: bent at waist; BC: ball carrier; Bk: back; BL: blank look; Fwd: forward; MT: mid trunk; LL: lower leg; LOC: loss of consciousness; LT: lower trunk; NA: not applicable; No.: number; T: tackler; UL: Upper leg; UT: upper trunk; v: versus; VS: vacant stare. \*Two video signs; seizure and tonic posturing, were not observed on retrospective video review of players that were removed from play for a head injury assessment but who were not diagnosed with a concussion. As such, seizure and tonic posturing have not been included in the video signs in this table.

**Table 5**

Frequency of concussion signs on video analysis in medically diagnosed concussions and players removed from play for a head injury assessment but who were not diagnosed with a concussion.

Video Signs	Concussions (n = 28)		Head Injury Assessments, No Concussion (n = 56)		Head Injury Assessments Total (n = 84)	
	f	%	f	%	f	%
Balance Disturbance/Motor Incoordination	19	67.9	42	75.0	61	70.9
Seizure	0	0	0	0	0	0
Tonic Posturing	0	0	0	0	0	0
No protective action	8	28.6	20	35.7	28	32.6
Dazed/Blank Stare/Vacant Look	7	25.0	18	32.1	25	29.1
Lying motionless	6	21.4	20	35.7	26	30.2
Slow to Stand	22	78.6	50	89.3	72	85.7
No signs observed	4	14.3	2	3.6	6	7.1
Number of Video Signs						
0	4	14.3	2	3.6	6	7.1
1	7	25.0	6	10.7	13	15.5
2	7	25.0	6	10.7	13	15.5
3	3	10.7	17	30.4	20	23.8
4	3	10.7	15	26.8	18	21.4
5	4	14.3	10	17.9	14	16.7
6	0	0	0	0	0	0

Note. There were 28 cases in the concussion group; 2 cases had a delayed diagnosis, so the possible video signs of concussion were not identified.

### 3.3. Return to play

Four out of the 30 concussed players sustained their concussion in the final game of the season (13.3%). These four players were not included in the games missed or the days to return analysis. There were three players who sustained a concussion 2, 7, or 8 weeks before the end of the season that did not return to any games for the rest of the season. These three players were included in the games missed analysis, but they were excluded in the days to return analysis. Of the 26 concussed players who sustained a concussion greater than one week before the end of the season, most (24/26, 92.3%) missed at least one game, while the remaining 2 (7.7%) did not miss any games. Of these 24 concussed players who returned to competition that season, the days to return to competition ranged from 7 to 41 days, with an average of 15.7 days.

## 4. Discussion

There are a limited number of studies relating to concussion in youth rugby league. The purpose of this study, involving two state-based youth (under 18s and under 20s) competitions, was to (i) report the rates of HIAs and medically diagnosed concussions; (ii) examine video signs of potential concussion; (iii) review game play risk factors related to HIAs and concussions; and (iv) determine the number of days until a concussed player returned to match play and the number of subsequent games missed by concussed players.

The present study revealed an HIA incidence rate of 5.13 and 17.48 HIAs per 1000 player match hours for the under 18s and under 20s competitions, respectively and the concussion incidence rate was 2.93 and 5.75 injuries per 1000 player match hours, respectively. This equates to a combined HIA incidence rate across both age groups of 14.61 per 1000 player match hours and a combined concussion incidence rate of 5.10 concussions per 1000 player match hours. This single season HIA incidence rate for under 18s is much lower, and for the under 20s competition is somewhat lower, than the single season HIA incident rate reported in the elite level under 20s Australian National Rugby League competition, which is estimated to have 22.4 HIAs per 1000 player match hours [16]. They are also considerably lower than the incidences reported at the NRL (elite level), which range from 24.0 (95% CI: 20.7–27.9)<sup>5</sup> to 34.78 HIAs per 1000 player match hours [21,24,33]. The concussion incidence rate was also lower than two pooled rugby league concussion incidence rates reported in 2014 [34] (7.7 [95% CI: 6.9–8.6] concussions per 1000 player match hours) and 2022 [35] (11.6 [95% CI: 10.8–12.5] concussions per 1000 player match hours). The combined concussion incidence rate reported in the current study examining two

QRL elite development pathway competitions appears similar to three previously reported junior competitions [17,36,37]. For instance, there are 4.6 concussions per 1000 player match hours in junior rugby league players [36], 4.6 concussion per 1000 player match hours in 17–18 year old Australian rugby league players [17], and 5.9 concussions per 1000 player match hours reported in under 19 and under 21 competitions [37]. The QRL elite development pathway concussion incidence rates were lower than the incidence rates across seven-seasons of English academy (under 19 years) rugby league (i.e., 14.3 concussions per 1000 player match hours [19]) and the New Zealand under 16 and under 18 players (i.e., 14.7 concussions per 1000 player match hours [20]). These differences may be attributable, at least in part, to the variations in game day injury surveillance systems for different competitions (e.g., sideline video review, multiple match day staff observing play).

A similar number of concussions were sustained by ball carriers and tacklers in the current study of QRL elite development pathway competitions (53.6% vs 48.2%). This finding is in contrast to most previous male rugby league studies that have reported more concussions and HIAs occur for a tackler than a ball carrier [5,6,31,38]. However, this result is similar to those reported in the elite women's premiership, the NRLW, where the ball carrier and tackler were also found to be equally likely to sustain a head impact event [21].

Many of the rugby league studies that have shown the tackler to be at greater risk for HIA and concussion provide support for an intervention to be focused on tackle technique [39,40] or rule modifications that put the onus on tacklers to reduce their tackle height [41,42]. Here, however, similar to the findings in the NRLW [21], the risk reduction approach should consider the behaviour of the ball carrier in addition to the tackler. Understanding the unique antecedent risk factors for a ball carrier (e.g., evasion technique, leg drive before and after contact, falling technique post contact, etc.) will be important for identifying a successful risk reduction intervention for concussion. For example, and consistent with previous research in elite [28] and sub-elite [31] male rugby league players, the risk for a concussion in the current study was greater when the ball carrier and the tackler both enter the tackle in an upright position.

Athletes playing in the forwards positions were three time more likely to be medically diagnosed with a concussion than players playing in the backs positions in the current study of QRL elite development pathway competitions, consistent with the findings in both the QRL [31] and the NRL [5]. This may be explained by the unique roles of forwards versus backs which results in a player being more or less susceptible to a concussion during match play. For example, forwards are more commonly involved in tackles, both as a tackler and as a ball carrier, and



the tackle is the most common game play event in rugby league [43–45]. Foul play, which is a potentially modifiable risk factor, accounted for approximately 7% of medically diagnosed concussions in the QRL elite development pathway competitions. This is slightly lower than the concussions that occurred due to foul play in the QRL (11%) [31] and the 20% of concussions reported in a preliminary study from three teams from the 2013 NRL season [27].

In the QRL elite development pathway under 18 and under 20 competitions the most commonly observed video sign was balance disturbance/motor incoordination, which was seen in approximately 68% of concussed players. This was similar to the percentage (72%) of QRL players [31] that were observed to display balance disturbance/motor incoordination. Balance disturbance/motor incoordination was not observed in as many concussed NRL players (25.5%) [24].

In the QRL elite development pathway competitions four out of five (80%) concussed players missed at least one subsequent game following a medically diagnosed concussion. This likely reflects, at least in part, a different medical management approach compared to the reported post-concussion return to play figures at the elite level, where only 12.1% of concussed players missed a subsequent game [5,16,23,28], and the sub-elite level where only 36.1% of concussed players missed a subsequent game [31]. These return to play differences may also be due to younger players taking longer to recover from concussions and complete the full return to play protocol than adults [46–49]. Youth players likely have less access to the close medical supervision and health care compared to professional athletes, and the professional athletes are highly financially motivated to recover quickly, which might also be factors in concussion recovery times. Taking a more cautious approach to return to play in youth athletes has been a consistent recommendation from experts for many years [1,14,50,51], and the present findings might reflect, at least in part, this approach for these injured athletes. After the 2019 season, rugby league has adopted a mandatory stand down period of 10 days across all levels of competition. This approach ensures that every player diagnosed with a concussion would not return to a game scheduled for the following weekend, that is, they would miss at least one game following concussion.

To put the results of the current study into context, and to help identify targeted intervention strategies for injury prevention specific to these two age-based competitions, future research should consider evaluating tackle events from the QRL under 18s and under 20s competitions that do not result in a HIA or a concussion. This will facilitate the calculation of propensity rates for risk factors associated with a HIA and concussion in these two age-based competitions and help with identifying specific interventions that may have a meaningful practical impact on HIA and concussion risk reduction.

#### 4.1. Limitations

Several limitations were present in this study. There was only a single camera angle available to review the incidents and videos were only coded by one researcher, which does not allow for calculating inter-rater reliability. The study only evaluated a single season of match play, so results of this study may not be generalisable to other seasons, women rugby league players, or other leagues. The current study did not have access to the full clinical profile of concussed athletes (e.g., symptom reporting, cognitive testing results, or clinical recovery time). Having these measures available would provide a more accurate recovery time than days to return to play or matches missed. The value that the presence or absence of video signs may have in relation to an athlete's medical diagnosis and clinical recovery could be the focus of future work in these age-based elite level development pathway competitions. Future research may also consider evaluating larger numbers of HIA and concussion cases to examine the interactions between multiple variables, not just analyse individual variables in isolation. For example, the unique roles of the playing positions (forwards versus backs) may result in greater exposure to high game play risk factors (speed of the tackler and

ball carrier, type of play, number of players in the tackle, etc.), which may increase or decrease the risk for a HIA or concussion. The current study did not consider any interactions between variables. In addition, the current study did not review every tackle in every match for the season. As such, it was not possible to report an incidence for “missed” Category 1 and Category 2 signs, which would enable the calculation of sensitivity, specificity, positive predictive value, and negative predictive value for each sign. It is possible that some HIAs may have been called as a tactical interchange, rather than a medical and welfare decision. If this was the case, then the true estimate of the HIA incidence in these youth rugby league competitions may be lower than reported here.

## 5. Conclusion

The concussion incidence rates in the two Queensland age-based (under 18s and under 20s) elite level development pathway competitions were lower than most previously reported rugby league concussion incidence rates. Players took longer to return to play in these competitions than other return to play figures reported in the rugby league literature at other levels of competition. Retrospective video review of known HIA and concussion events revealed multiple video signs were observed in most QRL under 18 and under 20 players who underwent a HIA or who were medically diagnosed with concussion. The evaluation of tackle events that do not result in a HIA or a concussion will help with identifying specific interventions for HIA and concussion risk mitigation in youth rugby league players.

### Ethics approval and consent to participate

The study was approved by The University of Newcastle's Human Ethics Committee (reference number: H-2015-0323) and was performed in accordance with the standards of ethics outlined in the Declaration of Helsinki.

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### Authors' contributions

MAL and AJG collected the data and created the database for analysis. MAL reviewed all videos and coded the HIA events. AJG provided primary supervision to MAL. DPT and GLI conceptualized and conducted the statistical analysis. AJG drafted the manuscript, and DPT and GLI drafted portions of the manuscript. All authors critically reviewed manuscript drafts and read and approved the submission of the final version.

### Consent for publication

Not applicable.

### Availability of data and material

All data used in this study have been presented in the tables in the manuscript.

### Declaration of competing interest

Andrew Gardner, Ph.D. has a clinical practice in neuropsychology involving individuals who have sustained sport-related concussion (including current and former athletes). He is a contracted concussion consultant to Rugby Australia. He is a member of the World Rugby Concussion Working Group, and a member of the Australian Football

League Concussion Scientific Advisory Committee. He has received travel funding or been reimbursed by professional sporting bodies, and commercial organisations for discussing or presenting sport-related concussion research at meetings, scientific conferences, workshops, and symposiums. Previous grant funding includes the NSW Sporting Injuries Committee, the Brain Foundation (Australia), an Australian-American Fulbright Commission Postdoctoral Award, a Hunter New England Local Health District, Research, Innovation and Partnerships Health Research & Translation Centre and Clinical Research Fellowship Scheme, and the Hunter Medical Research Institute (HMRI), supported by Jennie Thomas, and the HMRI, supported by Anne Greaves. He has also received research funding from the National Rugby League (NRL) to conduct research into the health of former professional rugby league players.

Martin A. Lang and Suzi Edwards have nothing to declare.

Grant Iverson, Ph.D. has been reimbursed by the government, professional scientific bodies, and commercial organizations for discussing or presenting research relating to mild TBI and sport-related concussion at meetings, scientific conferences, and symposiums. He has a clinical and consulting practice in forensic neuropsychology, including expert testimony, involving individuals who have sustained mild TBIs (including athletes). He has received research funding from several test publishing companies, including IMPACT Applications, Inc., CNS Vital Signs, and Psychological Assessment Resources (PAR, Inc.). He has received research funding from the National Football League. He has also received research funding from the Harvard Integrated Program to Protect and Improve the Health of National Football League Players Association Members.

Ben Jones, PhD, is employed by the Rugby Football League and Premiership Rugby in a consultancy capacity.

Douglas Terry, PhD., serves as a scientific advisor for HitIQ. He previously consulted for REACT Neuro, Inc. He has a consulting practice in forensic neuropsychology, including expert testimony, involving individuals who have sustained mild TBIs (including former athletes). He received research funding from Amgen, Inc. and Football Research Inc.

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