



## Original research

## National Rugby League match scheduling and rate of concussion

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## ABSTRACT

**Objectives:** The aims of this study were to evaluate the relationship between pre-match rest days, match location, time of season, and match outcome with diagnosed concussion and use of the Concussion Interchange Rule (CIR) during the 2014 NRL season.

**Design:** Descriptive observational study.

**Methods:** This study reviewed all instances of diagnosed concussions, CIR activations, and match characteristics during the 2014 NRL season. Information pertaining to the use of the CIR was obtained from the league. Each club provided information of diagnosed concussion.

**Results:** A total of 402 NRL games were analyzed, the concussion interchange rule was activated 167 times, and 60 concussions were diagnosed in 53 of the matches. A significantly greater proportion of concussions occurred during the first match of the season (38% vs. 15% of in-season matches;  $p = 0.02$ ). Days of rest, match location, season stage, and match outcome were not associated with a higher proportion of concussions. Furthermore, we did not detect a significant association between CIR activation and days of rest prior to the match, opponent rest prior to the match, match location, round of the season, or match outcome.

**Conclusions:** A significantly greater proportion of concussions were diagnosed during the first match of the season. Days between matches, opponent days of rest, match location, or other rounds (aside from round 1) of the season were not associated with CIR activation or diagnosed concussion. Varied game scheduling during the season does not appear to be associated with increased risk for concussion or use of the CIR in the NRL.

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## Practical implications

Concussions are a fairly common injury in the National Rugby League (NRL). The NRL has recently incorporated Thursday night and Monday night games, creating fewer days of rest between games. However, the reduced between-match time in the NRL has not been found to be associated with increased risk for concussion in this study.

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## 1. Introduction

Rugby league is a high intensity collision sport involving two teams of thirteen on-field players and four interchange players that can be switched in and out of the game without penalty. The game is played continuously in two 40-minute halves.<sup>1</sup> The National Rugby League (NRL) is the elite professional men's rugby league competition in Australia. Rugby league, like other full-contact and collision sports, has a risk of injury—in particular a risk of concussion.<sup>2</sup> A number of studies have examined the rate of concussion in the NRL and under 20s competitions.<sup>3–8</sup> The incidence rates of concussion in this sport may vary due to both risk factors (i.e., age and level of play) and methodological factors (i.e., differences in injury definitions, medical resources, or concussion expertise).<sup>2</sup> At the NRL level, a video analysis of diagnosed concussions among three clubs

**Table 1**

The association between match scheduling characteristics and games where a diagnosed concussion occurred (n = 402 total matches).

Match characteristic		Total matches	Matches with a diagnosed concussion	Matches without a diagnosed concussion	$\chi^2$ p value
Days of rest between matches	First match of season	16	6 (38%)	10 (63%)	0.02 <sup>*</sup>
	4 days	43	6 (14%)	37 (86%)	
	5–7 days	250	27 (11%)	223 (89%)	
	8–16 days	93	14 (15%)	79 (85%)	
Opponent days of rest between matches	First match of season	17	6 (35%)	12 (65%)	0.05
	4 days	48	5 (10%)	43 (90%)	
	5–7 days	243	31 (13%)	212 (87%)	
	8–16 days	94	11 (12%)	83 (88%)	
Match location	Home	203	25 (12%)	178 (88%)	0.80
	Away	198	28 (14%)	170 (86%)	
	Neutral	1	0 (0%)	1 (100%)	
Season stage	Rounds 1–10	160	24 (15%)	136 (85%)	0.54
	Rounds 11–20	127	17 (13%)	110 (87%)	
	Rounds 21–30	115	12 (10%)	103 (90%)	
Match outcome	Win	201	31 (15%)	170 (85%)	0.18
	Loss	201	22 (11%)	179 (89%)	

<sup>\*</sup> A concussion diagnosis occurred during a total of 53 matches.

during the 2013 season revealed an incidence rate of 14.8 concussions per 1000 player match hours,<sup>3</sup> and 8.92 concussions per 1000 player match hours for all clubs during the 2014 season.<sup>6</sup> To allow for evaluation of a suspected concussion, the NRL introduced the 'concussion interchange rule' (CIR) at the beginning of the 2014 season. The CIR allows a team physician to conduct a brief (up to 15 min) sideline evaluation of athletes with a suspected concussion. CIR activation leads to either a concussion diagnosis and subsequent removal from the match, or no concussion diagnosis and the athlete is free to return to the game without costing the team one of the twelve interchanges. The reported incidence rate was 24.03 uses of the CIR per 1000 NRL player match hours during the 2014 season.<sup>4</sup> At the national under 20s level (the National Youth Championship [NYC]), an incidence rate of 44.9 uses of the CIR per 1000 NYC player match hours has been reported.<sup>5</sup> The higher rates of CIR concussion diagnoses indicates that many suspected injuries do not result in a medical diagnosis of concussion.

The NRL has introduced game scheduling where matches occur on Thursday (at the beginning of the 2012 season) and Monday nights (at the beginning of the 2007 season), in addition to the traditional Friday night, Saturday afternoon and night, and Sunday afternoon schedule. This has resulted in clubs having shortened weeks (i.e., fewer days of rest between matches). Such a reduced rest time in between matches, as well as other factors such as game location, time of the season, or match outcome, have each been investigated as potential sources of increased injury risk among professional athletes.<sup>9</sup> The variation in each of these factors throughout a season presents challenges for players and team medical staff. The aim of this study was to examine whether rest time between matches, match venue, or time of season was associated with (i) a higher rate of concussion or (ii) with a more likely concussion diagnosis following CIR activation during the 2014 NRL season.

## 2. Materials and method

The current study identified all diagnosed concussions, uses of the CIR, and match and player characteristics for all 16 clubs for all games played in the 2014 NRL season. Each team plays 24 games and has two bye rounds in the regular season. Not all byes are played during the same weekend, thereby resulting in a longer (but variable) period of days of rest between games when a bye has been scheduled. The post-season (finals) format consists of 8 teams and

is played over 4 weeks. Each game is played between two teams and there are a total of 9 games in the series.

This study reviewed all instances where the CIR was activated and all instances of diagnosed concussion. Information pertaining to the use of the CIR was obtained from the NRL by the first author. Each club provided information for all cases of diagnosed concussion to the NRL as part of their injury reporting requirements. The club physician made the final diagnosis of concussion, based on conventional clinical examination techniques. This study was approved by the University of Newcastle Human Ethics Committee.

The variables of interest included 'days of rest between games' (categorical variable: first game of the season, 4 days, 5–7 days, or 8–16 days), 'season stage' (categorical variable: weeks 1–10, 11–20, and 21–30), 'match location' (categorical variable: home, away, or neutral), and 'match result' (categorical variable: win or loss). Playing position was determined via match reports and verified by reviewing match footage (categorical variable: forward, back, or interchange). We examined the variables of interest as they related to: (i) diagnosed concussions and (ii) the use of the CIR.

### 2.1. Statistical analysis

We used a series of Chi-square analyses to evaluate the relationship between our outcome variables and several predictor variables. The outcome variables were: (i) rate of diagnosed concussion, and (ii) rate of CIR activation during the season. The predictor variables were: (i) days of rest between matches for the index team and their opponent, match location, season stage, and match outcome. We also described the rate of individual athletes who activated the CIR multiple times during the season, and the relationship between multiple CIR activations with subsequent concussion diagnoses, season stage, match location, and playing position. Statistical significance was defined as a p value < 0.05. All statistical analyses were conducted using SPSS version 24 (IBM SPSS Statistics for Windows, Version 24; IBM Corp., Armonk, NY, USA).

## 3. Results

We analyzed data from 402 NRL games during the 2014 season. A concussion was diagnosed during 53 (13%) of the matches and the CIR was activated during 132 (33%) of the matches. The rate of concussion and the rate of use of the CIR during the 2014 NRL season was 8.63 and 24.03 per 1,000 NRL player match hours, respectively. A single concussion occurred in 47 matches, while two concussions

**Table 2**  
The association between match scheduling characteristics and games where the CIR was activated.

Match characteristic		Total matches	Matches with CIR activation <sup>a</sup>	Matches without CIR activation	$\chi^2$ p value
Days of rest between matches	First match of season	16	9 (56%)	7 (44%)	0.07
	4 days	43	11 (26%)	32 (74%)	
	5–7 days	250	76 (30%)	174 (70%)	
	8–16 days	93	36 (39%)	57 (61%)	
Opponent days of rest between matches	First match of season	17	9 (53%)	8 (46%)	0.34
	4 days	48	16 (33%)	32 (67%)	
	5–7 days	243	76 (31%)	167 (69%)	
	8–16 days	94	31 (33%)	63 (67%)	
Match location	Home	203	61 (30%)	142 (70%)	0.19
	Away	198	70 (35%)	128 (65%)	
	Neutral	1	1 (100%)	0 (0%)	
Season stage	Rounds 1–10	160	51 (32%)	109 (68%)	0.75
	Rounds 11–20	127	45 (35%)	82 (65%)	
	Rounds 21–30	115	36 (31%)	79 (69%)	
Match outcome	Win	201	71 (35%)	130 (65%)	0.18
	Loss	201	61 (30%)	140 (70%)	

<sup>a</sup> CIR activation occurred during a total of 132 matches.

**Table 3**  
The rate of concussion diagnoses among individual NRL athletes who activated the CIR multiple times throughout the 2014 season.

Number of CIR activations	Diagnosed concussions n, (%)	Season stage n, (%)	Match location n, (%)	Playing position n, (%)
First (n=26)	12 (46%)	Early: 17 (65%)	Home: 10 (38%)	Back: 6 (23%)
		Mid: 7 (27%)	Away: 15 (56%)	Forward: 18 (69%)
		Late: 2 (8%)	Neutral: 1 (4%)	Interchange: 2 (8%)
Second (n=26)	12 (46%)	Early: 7 (27%)	Home: 13 (50%)	Back: 4 (15%)
		Mid: 8 (31%)	Away: 13 (50%)	Forward: 18 (69%)
		Late: 11 (42%)		Interchange: 4 (15%)
Third (n=6)	1 (16%)	Early: 3 (50%)	Home: 1 (17%)	Forward: 5 (83%)
		Mid: 3 (50%)	Away: 5 (83%)	Interchange: 1 (17%)
		Late: 0 (0%)		
Fourth (n=3)	2 (67%)	Early: 1 (33%)	Home: 2 (67%)	Forward: 3 (100%)
		Mid: 1 (33%)	Away: 1 (33%)	
		Late: 1 (33%)		
Fifth, sixth, seventh (n=4)	2 (50%)	Mid: 3 (75%)	Home: 2 (50%)	Forward: 4 (100%)
		Late: 1 (25%)	Away: 1 (25%)	
			Neutral: 1 (25%)	

Note: CIR: concussion interchange rule; the number of activations over the course of the season is represented in the first column—most athletes had one or two activations in the season but a small number had 3 or more CIR activations during the season; Early: early season (rounds 1–10); Mid: middle of the season (i.e., rounds 11–20); Late: late season (rounds 21–26 and four-week final series).

occurred in 6 different matches. When the season was divided into halves, more concussions occurred during matches in the first 15 weeks of the season (n=34/220 matches; 15.5%) compared to the second 15 weeks of the season (n=19/182 matches; 10.4%). The proportion (based on the difference in the games played in the first and second 15 weeks of the season) was not significantly different ( $\chi^2 = 2.22$ ; p=0.18).

The distribution of the days of rest before a match was significantly different between matches with and without a concussion diagnosis (Table 1). Specifically, a higher proportion of concussions were diagnosed during the first match of the season compared to the games played during the rest of the season, regardless of the amount of rest between games (Table 1). The number of opponent days of rest, match location, season stage, and game outcome was not significantly associated with a higher proportion of concussions during NRL matches (Table 1). During the 6 matches that involved two diagnosed concussions, an even distribution was found for time of season (n=3 matches during the first half of the season, n=3 matches during the second half of the season), venue (n=3 home matches, n=3 away matches), and match outcome (n=3 win, n=3 loss).

The CIR was activated during a total of 132 matches. CIR activation was not significantly associated with days of rest between

matches, opponent days of rest between matches, match location, season stage, or match outcome (Table 2). There were 26 individual athletes who activated the CIR more than one time during the 2014 NRL season. Among these individuals, only six used the CIR more than twice (Table 3). Most (n=23, 88%) activated the CIR while playing the same position, while three were playing different positions at the time of each CIR activation.

#### 4. Discussion

Concussion management is an important issue for all contact and collision sports. Identifying potential risks of concussion are important for modifying and reducing the incidence of concussion. Game scheduling, particularly the days of rest between games for players and the opponent, the match location (i.e., travel schedules), the time during the season, and game outcome, may independently or in combination, play a role in modifying the risk of concussion. This study examined whether game scheduling in the NRL were associated with the rate of activation of the CIR or the rate of concussion. Of the factors investigated, we found that the concussion rate was higher during the first game of the season relative to the rest of the season, but no other significant associative factors.

There were a disproportionate number of concussions diagnosed in the first week compared to any another subsequent week in the season. The factors leading to this higher risk of concussion during the first game are likely multifactorial, and potentially relate to less conditioning, an increase in game-play intensity from pre-season training and trial games, or a heightened sensitivity (i.e., lower threshold) of medical staff to diagnose the injury. In a previous study, we reported a significant proportional difference between playing position and activation of the CIR (i.e., forwards = 57%, backs = 25%, and interchange players = 18%).<sup>4</sup>

There was no significant association between the days of rest and activation of the CIR or in-season days of rest and diagnosed concussion. As such the varied game schedule throughout the NRL season does not appear to be associated with a greater likelihood of CIR use or concussion. Specifically, there is no evidence based on the 2014 NRL season that fewer days rest and travel (i.e., away games or games played at a neutral venue) is associated with an increased use of the CIR or increased risk of concussion. There was no difference between game venues and use of the CIR.

The focus on NRL match scheduling and risk for possible and diagnosed concussion compliments the previously published work on the use of the CIR and diagnosed concussions during the 2014 NRL season.<sup>4</sup> In a previous study, we reported non-significant proportional differences in activation of the CIR for a number of variables: (i) the first half of matches (54% versus 45% for the second half and 0.6% for golden point extra time); (ii) tackle number in the set; (iii) location on the field where the incident occurred; (iv) the injured player's versus striking player's height and weight; (v) ball carrier versus tackler; (vi) number of defenders involved in the tackle; and (vii) illegal versus fair play.<sup>4</sup> The current study evaluated the potential association between NRL game scheduling and risk of CIR activation or risk of concussion, and found no significant associations between CIR activation or diagnosed concussion and days of rest between matches, opponent days of rest, match location, season stage, or match outcome.

There are a number of limitations associated with this study. First, collecting data for a single season resulted in a relatively small sample size, which reduced the statistical power. Second, this is an observational study, so no causal inferences can be drawn from the game scheduling and the activation of the CIR or diagnosed concussion. Finally, many individual player characteristics that may affect a player's vulnerability to concussion were not considered in this study. For example, the player's concussion history, playing position, number of tackles the player had been involved in prior to the incident, and player physical characteristics. Future studies may also examine whether the greater vulnerability during the first game of the season found in the current study is a robust finding, and evaluate the potential reasons that may have led to this higher risk of concussion during the first game.

## 5. Conclusions

Varied game scheduling does not appear to be associated with increased risk for concussion or use of the CIR in the NRL. Future research may evaluate multiple seasons for more robust analysis and results. Consideration of the game scheduling and other possible individual modifying factors such as a player's concussion history, physical conditioning, playing time in the indexed game, playing position, the time during the game that the incident occurred, number of tackles the player had been involved in prior to the incident, and player and opponent's height and weight, will also be important for more completely evaluating these possible associations.

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## References

- Hoskins W, Pollard H, Hough K, Tully C. Injury in rugby league. *J Sci Med Sport* 2006; 9(1–2):46–56.
- Gardner A, Iverson GL, Levi CR et al. A systematic review of concussion in rugby league. *Br J Sports Med* 2014; 49(8):495–498.
- Gardner AJ, Iverson GL, Quinn TN et al. A preliminary video analysis of concussion in the National Rugby League. *Brain Inj* 2015; 29(10):1182–1185.
- Gardner AJ, Iverson GL, Stanwell P, Ellis J, Levi CR. A video analysis of use of the new concussion interchange rule in the National Rugby League. *Int J Sports Med* 2016; 37(4):267–273.
- Gardner AJ, Kohler RMN, Levi CR, Iverson GL. Usefulness of video review of possible concussions in National Youth Rugby League. *Int J Sports Med* 2016; 38(1):71–75.
- Gardner AJ, Howell DR, Levi CR, Iverson GL. Evidence of concussion signs in National Rugby League match play: a video review and validation study. *Sport Med Open* 2017; 3(1):29.
- Gardner AJ, Levi CR, Iverson GL. Observational review and analysis of concussion: a method for conducting a standardised video analysis of concussion in rugby league. *Sport Med Open* 2017; 3(1):26.
- Gardner AJ, Wojtowicz M, Terry D, Levi CR, Zafonte RD, Iverson GL. Video and Clinical screening of Australian National Rugby League players suspected of sustaining concussion. *Brain Inj* 2017, in press.
- Lawrence DW, Comper P, Hutchison MG. Influence of extrinsic risk factors on National Football League Injury rates. *Orthop J Sport Med* 2016; 4(3), 232596711663922.