



## Concussion Incidence for Two Levels of Senior Amateur Rugby League in New Zealand, 2008-2011

King D<sup>1,2\*</sup>, Hume PA<sup>1,3</sup>, Cummins C<sup>2</sup>, Clark TN<sup>4</sup> and Gissane C<sup>5</sup>

<sup>1</sup>Department of Emergency, Sports Performance Research Institute New Zealand (SPRINZ), Auckland University of Technology, New Zealand

<sup>2</sup>Department of Science and Technology, University of New England, Australia

<sup>3</sup>Department of Health and Environmental Science, National Institute of Stroke and Applied Neuroscience (NISAN), Auckland University of Technology, New Zealand

<sup>4</sup>Department of Sport Performance, Australian College of Physical Education, Australia

<sup>5</sup>Department of Sport Health and Applied Science, St Mary's University, UK

### Abstract

**Aim:** To report the incidence, injury mechanisms and assessment of concussion in two levels of amateur senior rugby league over 2008-2011.

**Methods:** A prospective observational study of competition injuries in a New Zealand rugby league domestic club with two levels of participation (amateur representative, amateur premier domestic) between 2008-2011. All injuries were recorded on a standardised injury reporting form. Players were evaluated with the SCAT in 2008, and SCAT-2 in the 2009-2011 seasons as part of the health practitioner assessment. Differences were assessed by player level (club, representative), history of concussion (new, recurrent) and type of play (match, training).

**Results:** There were 43 matches and 434 training sessions resulting in 1,849 matches and 18,279 training exposure hr. There were 40 match-related and seven training-related concussions recorded. Concussion incidence was higher for the amateur representative players (37.2 per 1,000 match-hr) than the amateur premier domestic players (16.1 per 1,000 match-hr). The most common injury mechanism for a concussion was during the tackle to the ball-carrier. When compared with the tackler (5 per 1,000 match-hr), the ball carrier (13 per 1,000 match-hr) recorded three-fold more concussions. Highest concussion incidence occurred in the fourth quarter (38.9 per 1,000 match-hr) of matches. Most concussion injuries occurred in the fourth-quarter and second half of matches.

**Discussion:** Future studies should consider a longitudinal review incorporating recovery time, repeat concussion intervals, and differences in recovery time, for players with recurrent concussions in the same year against repeat concussions over the longitudinal period.

What is known about the subject?

- The number of concussions that occur in rugby league have varied depending upon the level of participation and the injury definition utilised,
- Concussion epidemiology is limited by the lack of empirical data as most studies are typically on one team for a limited period,
- Concussion is typically reported as part of wider studies reporting on the incidence of injuries in match and training rugby league studies.

What this study adds to existing knowledge?

- At the amateur rugby league level of participation, the incidence of concussion is higher than professional rugby league,
- Inclusion of symptom indices can assist with the identification of the distress the concussed player is undergoing as a result of the concussive injury.

**Keywords:** Rugby league; Concussion; Mild traumatic brain injury; Match; Training

### OPEN ACCESS

#### \*Correspondence:

Doug King, Department of Emergency,  
Hutt Valley District, Health Board  
Private Bag 31-907 Lower Hutt,  
Auckland University of Technology, New  
Zealand,

E-mail: [dking@aut.ac.nz](mailto:dking@aut.ac.nz)

Received Date: 06 Jan 2018

Accepted Date: 08 Feb 2018

Published Date: 15 Feb 2018

#### Citation:

King D, Hume PA, Cummins C, Clark TN, Gissane C. Concussion Incidence for Two Levels of Senior Amateur Rugby League in New Zealand, 2008-2011. *Sports Med Rehabil J.* 2018; 3(1): 1026.

**Copyright** © 2018 King D. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

## Introduction

Rugby league is an intermittent contact team-sport in which players compete with a combination of muscular strength, stamina, endurance, speed, acceleration, agility, flexibility and aerobic endurance [1]. During match-play, players are involved in 29 to 59 physical collisions (16 to 42 tackles; 13 to 17 hit-ups) depending upon positional group or playing role [2,3]. As such, there is a risk of injury in both matches and training due to the number of physical collisions [4]. One injury that has received attention in contact sports is concussion, or mild traumatic brain injury.

The incidence of concussion in rugby league varies from 2.5 [5] (professional) to 34.8 [6] (semi-professional) per 1,000 match-hr. A pooled analysis [7] reported that the epidemiology of concussion varied by participation level from 6 (semi-professional) to 18 (amateur) per 1,000 match-hr and 0.01 (professional) to 3.1 (amateur) per 1,000 training-hr. These rates were less than a systematic review [8] where the incidence of concussion varied from 0 to 40 per 1,000 playing-hr depending on the injury definition utilised (time loss vs. no time loss). Although studies have reported on the epidemiology of concussions [7,8], small short-term studies [9-12], longitudinal professional rugby league [13], pooled analysis [14], systematic review [8], video analysis [15], related economic costs [16,17] or have included the incidence of concussion in rugby league match [18,19] and training [20,21] activities, no study has specifically reported the incidence, injury mechanisms and assessment of concussion in senior amateur rugby league in New Zealand. The aim of this study therefore, was to review the incidence, injury mechanisms and incidence of concussion in two levels of amateur senior rugby league over 2008-2011 in New Zealand.

## Methods

A prospective observational cohort study was undertaken for two amateur rugby league teams over four consecutive years (2008 to 2011). The researcher's university ethics committee (AUTEK 16/35) approved all procedures in the study and all players gave informed signed consent prior to participating in the study.

The first team comprised participants of a single Wellington (New Zealand) amateur domestic club-based rugby league team participating in the zonal senior premier domestic competition. A total of 298 players (145 forwards, 153 backs) participated in the domestic competitions with 107 players (47 forwards, 60 backs) competing in more than one season. The zonal domestic competition season commenced in December through to August with competition matches played from March to August. The second team was a senior amateur Wellington zonal representative team comprising of players selected from all eight premier teams competing in the regional zonal competition. The team participated in the senior representative competition of five zonal teams throughout New Zealand from August through to October each year. A total of 106 players took part (63 forwards; 43 backs) with 27 players (13 forwards; 14 backs) participating in more than one competition season. As a result, 404 players (208 forwards, 196 backs) participated with 134 players (60 forwards, 74 backs) participating in more than one season. Twenty-five players (12 forwards; 13 backs) participated in both amateur premier domestic club and representative competition teams. All players were considered amateur as they derived their main source of income from other means without receiving match payments. Players were categorized into positional roles; forwards (props, hooker, second row forwards and loose forward) or backs (half-back,

standoff, centers, wings and full-back) [22] and positional groups; hit-up forwards (props, second row forwards), outside backs (centers, wings) or adjustable (hooker, loose forward, half-back, standoff, full-back) [23].

The team medic, a registered comprehensive nurse with tertiary sports medicine qualifications in injury prevention, assessment and management was present at every match and training session, including preseason fixtures, routinely recorded all injuries that occurred irrespective of injury severity. The assessment of injuries has been previously reported [22]. Data collected on the injury reporting form were transcribed onto a Microsoft Excel spreadsheet for collation. All data were de-identified at the time of recording and included a unique eight digit alpha-numerical code, playing position at time of injury, nature of injury (site, type, mechanism, severity [24]) and Orchard Sports Injury Classification (OSICS) code [25]. Match and training injury exposure and injury rates were calculated as previously reported [24].

The New Zealand Rugby League (NZRL) concussion policy guidelines reflect the 'Concussion in Sport' group consensus statements on the definition, assessment and management strategies for sports related concussions ([http://www.nzrl.co.nz/media/22461/concussion\\_policy\\_sept\\_2010.pdf](http://www.nzrl.co.nz/media/22461/concussion_policy_sept_2010.pdf)) [26]. This policy was adhered to throughout the study duration. Players observed receiving a direct blow to the head, and/or were slow to rise from a tackle or collision and/or appeared unsteady on their feet following a collision, were assessed on-field for injury. Any signs of delayed answering, incorrect answers to questions or, if the player appeared to be impaired in any way, resulted in the player being removed from the activity and rested on the sideline. No player removed from any match or training activity was allowed to return to participation in the same day. The player was reassessed approximately five minutes later utilising established guidelines. All suspected concussions were referred to a health practitioner for further assessment and management.

Concussion was defined as "any disturbance in brain function caused by a direct or indirect force to the head. It results in a variety of non-specific symptoms and often does not involve loss of consciousness. Concussion should be suspected in the presence of any one or more of the following: (a) Symptoms (such as headache), or (b) Physical signs (such as unsteadiness), or (c) Impaired brain function (e.g. confusion) or (d) Abnormal behaviour" [26]. Recurrent concussion was defined as "Any concussion that occurs to the same player in the same competition year." All players medically diagnosed with a concussion were stood down for the minimum stand down period of 21 days (as per the NZRL Concussion Protocol), undertook a graduated return-to-play program and required a full medical clearance before returning to full training and match-play [26]. Only players medically diagnosed as having a concussion by the health practitioner were included for analysis in this study.

As part of the post-match-assessment by the health practitioner and during the stand down period, concussions were assessed with the Sport Concussion Assessment Tool (SCAT 1 in 2008 and SCAT-2 in the 2009 to 2011 competition seasons) [27,28]. The SCAT contains separate test domains to assess total number of symptoms (0-22; higher score=more symptoms), symptom severity (0-132; higher score=more severe symptoms); total Standardized Assessment of Concussion (SAC) (0-30; lower score=worse cognitive performance), and a modified Balance Error Scoring System (mBESS) of three stances on a hard floor (0-30; higher score=lower number of errors).

**Table 1:** Concussions that occurred during 2008 to 2011 for total, club and representative amateur senior male rugby league players by observed and expected concussions, number of matches, exposure hours, injury rate, hours per concussion, total per session, player appearances and minutes played per concussion for training and match activities by rates per 1,000 with 95% confidence intervals.

	Club Matches	Representative Matches	Total Matches
Concussions Observed	22 <sup>b</sup>	18 <sup>a</sup>	40
Concussions Expected	29.5	10.5	40
No. of matches played	24	19	43
Exposure Hours <sup>c</sup>	1,365.90	484	1,849.90
Injury rate per 1,000 match hours (95% CI)	16.1 (10.6 to 24.5)	37.2 (23.4 to 59.0)	21.6 (15.9 to 29.5)
Hours per concussion (95% CI)	62.1 (40.9 to 94.3)	26.9 (16.9 to 42.7)	46.2 (33.9 to 63.0)
Total number concussions per match (95% CI)	0.9 (0.6 to 1.4)	0.9 (0.6 to 1.5)	0.9 (0.7 to 1.3)
Player appearances per concussion (95% CI)	16.4 (10.8 to 24.9)	15.8 (10.0 to 25.1)	16.1 (11.8 to 22.0)
Match minutes played per concussion (95% CI)	87.3 (57.5 to 132.5)	84.4 (53.2 to 134.0)	86.0 (63.1 to 117.2)
	Club Trainings	Representative Trainings	Total Trainings
Concussions Observed	5	2	7
Concussions Expected	5.9	1.1	7
No. of training sessions	384	50	434
Exposure Hours	15,304.00	2,975.60	18,279.60
Injury rate per 1,000 training hours (95% CI)	0.3 (0.1-0.8)	0.7 (0.2-2.7)	0.4 (0.2-0.8)
Hours per concussion (95% CI)	3,060.8 (1,274.0-7,353.8)	1,487.8 (372.1-5,949.0)	2,611.4 (1,244.9-5,477.7)
Total number concussions per training (95% CI)	0.01 (0.01-0.03)	0.04 (0.01-0.16)	0.02 (0.01-0.03)
Player appearances per concussion (95% CI)	1,152.0 (497.5-2,767.8)	375.0 (93.8-1,499.5)	930.0 (443.4-1,950.8)
Training minutes completed per concussion (95% CI)	6,144.0 (2,557.3-14,761.4)	2,000.0 (500.2-7,997.1)	4,960.0 (2,364.6-10,404.3)

CI=Confidence Intervals; <sup>c</sup>=based on match duration of 80 minutes; Significant difference ( $p < 0.05$ ) for <sup>a</sup>Club matches; <sup>b</sup>=Representative.

The timed tandem gait measure and coordination test was not included in the final analysis as not all players had this recorded. The cognitive assessment in the SAC comprises four components: orientation (0-5), immediate memory (0-15), concentration (digits backwards and months in reverse order, 0-5) and delayed recall (0-5). The instructions for conducting the SCAT assessment were read out on the SCAT and SCAT-2 form to ensure continuity of assessment. Although the SCAT and SCAT 2 were superseded by the SCAT-3 [29], the components of these assessment formats are similar. To evaluate the SCAT components in the current study, the following guidelines for concussion assessment were utilised [30]:

- A. Symptom Evaluation
  - a. Score (range 1-22): 3 or more symptoms from baseline; and/or
  - b. Severity (range 1-132): score of 11 or more.
- B. Cognitive Assessment
  - a. Orientation (range 0-5): 1 less than baseline; and/or
  - b. Immediate Memory (range 0-15): 12 or less; and/or
  - c. Concentration (range 1-5): 3 or less for numbers reversed; and/or
  - d. Delayed recall (range 0-5): 3 or less.
- C. SAC (range 0-30): combined score of 27 or less; and
- D. Modified Balance Scoring System (range 0-30): more than three errors in double and/or tandem stance from baseline.

In addition to the symptom evaluation scales, symptom indices

were applied to the symptom score and severity. The symptoms indices were the Global Severity Index (GSI) providing an overall summary measure of the symptoms on a scale from 0 to 6, and the Positive Symptom Distress Index (PSDI) to measure the intensity of the symptoms the player reported on a scale from 0 to 6 [31].

### Statistical analyses

De-identified data were examined for the OSICS code HN1 (concussion) and analysed with SPSS (IBM Corp, Released 2017. IBM SPSS Statistics for Windows, Version 24.0 Armonk, NY: IBM Corp). Differences in concussion were assessed by player level (club, representative), history of concussion (new, recurrent) and type of play (match, training). A one-sample chi-squared ( $\chi^2$ ) test determined whether the observed match and training exposures and injury frequency were significantly different from the expected exposure and injury frequency. To compare concussion injury rates, risk ratios (RR's) were utilised. SCAT components were not normally distributed (Shapiro-Wilk;  $W_{(52)}=0.94$ ;  $p < 0.0001$ ) and data for SCAT components are reported as median (IQR). SAC components were analysed using a Friedman repeated measures ANOVA on ranks. If significant differences were observed a post-hoc analysis was undertaken by a Wilcoxon signed-rank test. Results were considered significant at  $p < 0.05$ .

### Results

Altogether 384 trainings and 79 matches were completed by the club team (Table 1). There were five concussions during trainings (0.3 (95% CI: 0.1 to 0.8) per 1,000 training-hr) and 22 concussions in matches (16.1 (95% CI: 10.6 to 24.5) per 1,000 match-hr) throughout the study. Fifty trainings and 28 matches were completed by the representative team. There were two concussions recorded during

**Table 2:** Incidence of concussions during match and training participation by player position, player role, player group, match period, match half, loss of consciousness and injury mechanism for amateur male rugby league players in New Zealand over 2008 to 2011 for a club and representative team and total matches by number, rate per 1,000 match hours with 95% confidence intervals and percentage (%) of concussions recorded.

	No	Club Match Rate (95% CI)	%	No	Representative Match Rate (95% CI)	%	No	Total Match Rate (95% CI)	%
<b>Match Participation</b>									
No. 1 Fullback	4	38.1 (14.3-101.4)	18.2	3	80.6 (26.0-249.8)	16.7	7	49.2 (23.5-103.2)	17.5
No. 2 Wing	2	19.0 (4.8-76.1)	9.1	0	0.0 -	0	2	14.1 (3.5-56.2)	5
No. 3 Centre	2	19.0 (4.8-76.1)	9.1	1	26.9 (3.8-190.7)	5.6	3	21.1 (6.8-65.4)	7.5
No. 4 Centre	1	9.5 (1.3-67.6)	4.5	2	53.7 (13.4-214.8)	11.1	3	21.1 (6.8-65.4)	7.5
No. 5 Wing	0	0.0 -	0	3	80.6 (26.0-249.8)	16.7	3	21.1 (6.8-65.4)	7.5
No. 6 Stand off	0	0.0 -	0	2	53.7 (13.4-214.8)	11.1	2	14.1 (3.5-56.2)	5
No. 7 Half back	2	19.0 (4.8-76.1)	9.1	0	0.0 -	0	2	14.1 (3.5-56.2)	5
No. 8 Prop	1	9.5 (1.3-67.6)	4.5	0	0.0 -	0	1	7.0 (1.0-49.9)	2.5
No. 9 Hooker	3	28.6 (9.2-88.5)	13.6	2	53.7 (13.4-214.8)	11.1	5	35.2 (14.6-84.5)	12.5
No. 10 Prop	2	19.0 (4.8-76.1)	9.1	2	53.7 (13.4-214.8)	11.1	4	28.1 (10.6-74.9)	10
No. 11 Second row	2	19.0 (4.8-76.1)	9.1	1	26.9 (3.8-190.7)	5.6	3	21.1 (6.8-65.4)	7.5
No. 12 Second row	1	9.5 (1.3-67.6)	4.5	2	53.7 (13.4-214.8)	11.1	3	21.1 (6.8-65.4)	7.5
No. 13 Loose forward	2	19.0 (4.8-76.1)	9.1	0	0.0 -	0	2	14.1 (3.5-56.2)	5
<b>Player Role</b>									
Outside backs	5 <sup>b</sup>	11.9 (5.0-28.6)	22.7	6 <sup>a</sup>	40.3 (18.1-89.7)	33.3	11	19.3 (10.7-34.9)	27.5
Adjustable	11	20.9 (11.6-37.8)	50	7	37.6 (17.9-78.9)	38.9	18	25.3 (15.9-40.2)	45
Hit-up forwards	6	14.3 (6.4-31.8)	27.3	5	33.6 (14.0-80.7)	27.8	11	19.3 (10.7-34.9)	27.5
<b>Player Group</b>									
Backs	11 <sup>b</sup>	15.0 (8.3-27.0)	50	11 <sup>a</sup>	42.2 (23.4-76.2)	61.1	22	22.1 (14.5-33.6)	55
Forwards	11	17.4 (9.7-31.5)	50	7	31.3 (14.9-65.7)	38.9	18	21.1 (13.3-33.5)	45
<b>Match Period</b>									
1 <sup>st</sup> quarter	3	8.8 (2.8-27.2)	13.6	2 <sup>e</sup>	16.5 (4.1-66.1)	11.1	5 <sup>e</sup>	10.8 (4.5-26.0)	12.5
2 <sup>nd</sup> quarter	4	11.7 (4.4-31.2)	18.2	2 <sup>e</sup>	16.5 (4.1-66.1)	11.1	6 <sup>e</sup>	13.0 (5.8-28.9)	15
3 <sup>rd</sup> quarter	6	17.6 (7.9-39.1)	27.3	5	41.3 (17.2-99.3)	27.8	11	23.8 (13.2-42.9)	27.5
4 <sup>th</sup> quarter	9 <sup>b</sup>	26.4 (13.7-50.7)	40.9	9 <sup>acd</sup>	74.4 (38.7-143.0)	50	18 <sup>cd</sup>	38.9 (24.5-61.8)	45
<b>Match Half</b>									
1 <sup>st</sup> half	7	10.2 (4.9-21.5)	31.8	4 <sup>g</sup>	16.5 (6.2-44.0)	22.2	11 <sup>g</sup>	11.9 (6.6-21.5)	27.5
2 <sup>nd</sup> half	15 <sup>b</sup>	22.0 (13.2-36.4)	68.2	14 <sup>af</sup>	57.9 (34.3-97.7)	77.8	29 <sup>f</sup>	31.4 (21.8-45.1)	72.5
<b>Concussion Occurrence</b>									
Season new	18 <sup>i</sup>	13.2 (8.3-20.9)	81.8	12	24.8 (14.1-43.7)	66.7	30 <sup>i</sup>	16.2 (11.3-23.2)	75
Season recurring	4 <sup>bh</sup>	2.9 (1.1-7.8)	18.2	6 <sup>a</sup>	12.4 (5.6-27.6)	33.3	10 <sup>h</sup>	5.4 (2.9-10.0)	25
<b>Concussion Type</b>									
No LOC	16 <sup>bkl</sup>	11.7 (7.2-19.1)	72.7	13 <sup>akl</sup>	26.9 (15.6-46.3)	72.2	29 <sup>kl</sup>	15.7 (10.9-22.6)	72.5
<5 s LOC	5 <sup>j</sup>	3.7 (1.5-8.8)	22.7	4 <sup>j</sup>	8.3 (3.1-22.0)	22.2	9 <sup>jl</sup>	4.9 (2.5-9.4)	22.5
>5 s LOC	1 <sup>j</sup>	0.7 (0.1-5.2)	4.6	1 <sup>j</sup>	2.1 (0.3-14.7)	5.6	2 <sup>jk</sup>	1.1 (0.3-4.3)	5
<b>Injury Mechanism</b>									
Tackler	5	3.7 (1.5-8.8)	22.7	4	8.3 (3.1-22.0)	22.2	9 <sup>n</sup>	4.9 (2.5-9.4)	22.5
Ball carrier	13 <sup>bo</sup>	9.5 (5.5-16.4)	59.1	11 <sup>ao</sup>	12.4 (5.6-27.6)	61.1	24 <sup>mo</sup>	13.0 (8.7-19.4)	60
Other	4 <sup>n</sup>	2.9 (1.1-7.8)	18.2	3 <sup>n</sup>	6.2 (2.0-19.2)	16.7	7 <sup>n</sup>	3.8 (1.8-7.9)	17.5
<b>Training Participation</b>									
<b>Player Group</b>									
Backs	3	0.5 (0.2-1.5)	60	2	1.7 (0.4-6.6)	100	5	0.6 (0.3-1.5)	71.4
Forwards	2	0.3 (0.1-1.4)	40	0	0.0 -	0	2	0.2 (0.1-0.9)	28.6

Training Period									
1 <sup>st</sup> quarter	0	0.0 -	0	0	0.0 -	0	0	0.0 -	0
2 <sup>nd</sup> quarter	3	0.8 (0.3-2.4)	60	0	0.0 -	0	3	0.6 (0.2-2.0)	42.9
3 <sup>rd</sup> quarter	1	0.3 (0.0-1.9)	20	1	1.3 (0.2-9.5)	50	2	0.4 (0.1-1.7)	28.6
4 <sup>th</sup> quarter	1	0.3 (0.0-1.9)	20	1	0.3 (0.2-9.5)	50	2	0.4 (0.1-1.7)	28.6
Training Half									
1 <sup>st</sup> half	3	0.4 (0.1-1.2)	60	0	0.0 -	0	3	0.3 (0.1-1.0)	42.9
2 <sup>nd</sup> half	2	0.3 (0.1-1.0)	40	2	1.3 (0.3-5.4)	100	4	0.4 (0.2-1.2)	57.1
Season									
New	4	0.3 (0.1-0.7)	80	2	0.7 (0.2-2.7)	100	6	0.3 (0.1-0.7)	85.7
Recurring	1	0.1 (0.0-0.5)	20	0	0.0 -	0	1	0.1 (0.0-0.4)	14.3
Loss of Consciousness									
No LOC	5	0.3 (0.1-0.8)	100	2	0.7 (0.2-2.7)	100	7	0.4 (0.2-0.8)	100
Injury Mechanism									
Tackler	0	0.0 -	0	0	0.0 -	0	0	0.0 -	0
Tackled	3	0.2 (0.1-0.6)	60	2	0.7 (0.2-2.7)	100	5	0.3 (0.1-0.7)	71.4
Other	2	0.1 (0.0-0.5)	40	0	0.0 -	0	2	0.1 (0.0-0.4)	28.6

CI=Confidence Interval; LOC=loss of consciousness; <sup>s</sup>=seconds; Other=fall, collision with other player, collision with ground; Significant difference (p<0.05) for <sup>a</sup>=Club Matches; <sup>b</sup>=Representative Matches; <sup>c</sup>=1<sup>st</sup> match period; <sup>d</sup>=2<sup>nd</sup> match period; <sup>e</sup>=4<sup>th</sup> match period; <sup>f</sup>=1<sup>st</sup> half; <sup>g</sup>=2<sup>nd</sup> half; <sup>h</sup>=season new; <sup>i</sup>=season recurring; <sup>j</sup>=no LOC; <sup>k</sup>=<5 sec LOC; <sup>l</sup>=>5 sec LOC; <sup>m</sup>=Tackler; <sup>n</sup>=Ball Carrier; <sup>o</sup>=Other.

training (0.7 (95% CI: 0.2 to 2.7) per 1,000 training-hr) and 18 concussions during matches (37.2 (95% CI: 23.4 to 59.0) per 1,000 match-hr). Club players recorded more match ( $\chi^2_{(1)}=24.3$ ; p<0.0001) and training ( $\chi^2_{(1)}=257.0$ ; p<0.0001) concussions than zonal representative players. Consequently, club players recorded more match (RR: 2.3 (95% CI: 1.3 to 4.3); p=0.0067) and training (RR: 2.1 (95% CI: 0.4 to 10.6); p=0.3783) concussions than representative players.

At club level, the fullback recorded the most concussions (38.1 (95% CI: 14.3 to 101.4) per 1,000 match-hr) (Table 1). In the representative team, the fullback and No. 5 (wing) recorded the most concussions (80.6 (95% CI: 26.0 to 249.8) per 1,000 match-hr). As such, the fullback recorded the most concussions (49.2 (23.5 to 103.2) per 1,000 match-hr) when all match data was combined. Outside backs recorded more concussions at representative (40.3 (95% CI: 18.1 to 89.7) per 1,000 match-hr) than club (11.9 (95% CI: 5.0 to 28.6) per 1,000 match-hr; RR: 3.4 (95% CI: 1.0 to 11.1); p=0.0322) levels of participation. There were more concussions recorded as the ball carrier when a concussion occurred at representative (12.4 (95% CI: 5.6 to 27.6) per 1,000 match-hr) than club (9.5 (95% CI: 5.5 to 16.4) per 1,000 match hr; RR: 2.4 (95% CI: 1.1 to 5.3); p=0.0284) levels of participation. Most concussions occurred without loss-of-consciousness at club (72.7%) and representative (72.2%) levels.

Although there were more concussions recorded in the first (0.4 (95% CI: 0.1 to 1.2) per 1,000 training-hr) than the second (0.3 (95% CI: 0.1 to 1.0) per 1,000 training hr; RR: 1.5 (95% CI: 0.3 to 9.0); p=0.6547) half of training sessions at the club level this was not significant (Table 2). All concussions that were recorded at trainings occurred without loss of consciousness, and most (71.4%) were sustained by the ball carrier when tackled. There was a median of 14.5 (IQR: 9.0-15.8) symptoms reported with a symptom severity of 29.5 (IQR: 17.0-48.8) for players concussed during matches throughout the study (Table 3). Representative players with a recurrent concussion sustained a higher median symptom score ( $\chi^2_{(1)}=5.0$ ; p=0.0253),

symptom severity ( $\chi^2_{(1)}=6.0$  p=0.0143) and had higher GSI ( $\chi^2_{(1)}=6.0$ ; p=0.0143) and PSDI ( $\chi^2_{(1)}=6.0$ ; p=0.0143) scores when compared with representative players with a new concussion. Players reporting a recurrent concussion had a lower median SAC score at club (18.0 (IQR: 8.8-25.8) vs. 24.5 (IQR: 21.8-26.0); p=0.4615), representative (23.5(IQR: 20.3-25.0) vs. 25.5 (24.0-26.8); p=0.0578) and when combined (23.5 (IQR: 11.8-25.0) vs. 25.0 (IQR: 23.0-26.0); p=0.2614) when compared with players reporting a new concussion.

## Discussion

This is the first study reporting the epidemiology of concussions at an amateur playing level in New Zealand, through reviewing the incidence, injury mechanisms and assessment of concussion in two levels of amateur senior rugby league over 2008-2011. Concussion incidence at the club and representative levels of participation varied from 16.1 to 37.2 per 1,000 match-hr and 0.3 to 0.7 per 1,000 training-hr. When compared with professional rugby league [13], the incidence of match-related concussions was 28.3 per 1,000 match-hr which is higher than club, but lower than representative matches. The incidence of in-season recurrent concussions for the zonal representative competition was similar to the professional level of participation (15.1 per 1,000 match-hr) but higher than club participation. The differences may be related to an increased level of participation at the representative as opposed to club level. Further, the differences could be related to representative participants exhibiting a higher playing intensity than club participants, thereby resulting in an increased concussion incidence. No physiological assessments were however, conducted within this study and there are no other published studies reporting on the epidemiology of concussion in rugby league at any other level of participation therefore, ruling out further comparisons. Further research is warranted to compare the anthropometric characteristics of club and representative participants and the incidence of concussions in amateur rugby league.

The fullback was most commonly concussed at the club level of participation and the fullback and wing at the representative level

**Table 3:** Median and 25<sup>th</sup> to 75<sup>th</sup> interquartile ranges of the SCAT and SCAT 2 [27,28] scores with Global Severity Index and Positive Symptoms Distress Index results for new [31], recurrent and combined totals by club, representative and total concussions recorded for match and training activities in amateur senior male rugby league players in New Zealand.

	Club concussions			Representative concussions			Total concussions		
	New Median [IQR]	Recurrent Median [IQR]	Combined Median [IQR]	New Median [IQR]	Recurrent Median [IQR]	Combined Median [IQR]	New Median [IQR]	Recurrent Median [IQR]	Combined Median [IQR]
<b>Match Concussions</b>									
<b>Symptom Assessment</b>									
Score (22)	11.0 [9.0-16.0]	19.0 [18.0-21.5]	14.5 [9.0-18.0]	<b>11.5 [8.3-14.0]<sup>d</sup></b>	<b>14.5 [13.8-15.8]<sup>e</sup></b>	14.0 [10.5-14.3]	11.0 [9.0-15.0]	16.5 [14.0-18.5]	14.5 [9.0-15.8]
GSI (6)	0.9 [0.6-1.9]	3.6 [2.0-3.8]	1.3 [0.7-3.8]	<b>1.0 [0.7-1.5]<sup>d</sup></b>	<b>2.5 [1.5-3.0]<sup>e</sup></b>	1.4 [0.8-1.9]	0.9 [0.7-1.6]	2.5 [1.5-3.7]	1.3 [0.8-2.2]
Severity (132)	20.5 [13.5-41.0]	78.0 [42.8-83.3]	29.5 [16.3-66.0]	<b>22.5 [15.5-33.5]<sup>d</sup></b>	<b>48.0 [31.8-67.0]<sup>e</sup></b>	30.0 [17.0-41.3]	20.5 [0.7-1.6]	55.5 [32.8-81.8]	<b>29.5 [17.0-48.8]<sup>f</sup></b>
PSDI (6)	2.0 [1.5-2.9]	3.8 [2.2-4.4]	2.0 [1.5-3.5]	<b>2.0 [1.8-2.6]<sup>d</sup></b>	<b>3.3 [2.4-4.2]<sup>e</sup></b>	2.2 [1.8-2.8]	2.0 [1.5-2.6]	3.5 [2.4-4.3]	2.0 [1.7-3.1]
<b>Cognitive Assessment</b>									
Orientation (5)	4.0 [4.0-5.0]	3.5 [1.5-4.8]	4.0 [4.0-5.0]	5.0 [4.3-5.0]	4.0 [3.0-5.0]	5.0 [3.8-5.0]	5.0 [4.0-5.0]	4.0 [3.0-5.0]	4.5 [4.0-5.0]
Immediate memory (15)	14.0 [13.0-15.0]	10.5 [6.3-14.8]	14.0 [12.8-15.0]	13.5 [13.0-14.0]	14.0 [11.3-14.3]	14.0 [13.0-14.0]	14.0 [13.0-14.3]	14.0 [6.8-14.3]	14.0 [13.0-15.0]
Concentration (5)	3.0 [1.0-4.0]	1.5 [1.0-2.8]	3.0 [1.0-3.3]	2.5 [2.0-3.0]	2.0 [1.0-3.0]	2.0 [2.0-3.0]	3.0 [2.0-3.0]	2.0 [1.0-3.0]	3.0 [1.3-3.0]
Delayed recall (5)	<b>4.0 [2.8-4.3]<sup>b</sup></b>	1.5 [0.0-4.5]	3.5 [1.8-4.3]	<b>5.0 [4.0-5.0]<sup>a</sup></b>	3.5 [2.0-4.3]	4.0 [3.8-5.0]	4.0 [3.0-5.0]	3.0 [1.5-4.3]	3.5 [3.0-5.0]
<b>SAC (30)</b>									
Total Score	24.5 [21.8-26.0]	18.0 [8.8-25.8]	24.5 [20.8-26.0]	25.5 [24.0-26.8]	23.5 [20.3-25.0]	24.5 [23.0-26.0]	25.0 [23.0-26.0]	23.5 [11.8-25.0]	24.5 [23.0-26.0]
<b>BESS (30)</b>									
Total Score	22.5 [16.0-26.0]	23.0 [15.0-29.5]	22.5 [16.0-26.3]	24.0 [14.5-29.5]	24.0 [9.0-27.3]	24.0 [14.0-28.8]	22.5 [16.0-27.3]	24.0 [13.0-28.0]	22.5 [16.0-27.8]
<b>Training Concussions</b>									
<b>Symptom Assessment</b>									
Score (22)	10.0 [8.0-11.5]	13 <sup>*</sup>	10.5 [9.0-12.3]	5.0 [3.8-10.3]	-	5.0 [3.8-10.3]	10.0 [5.3-11.8]	13 <sup>*</sup>	10.0 [2.3-11.8]
GSI (6)	0.8 [0.6-1.2]	1	0.8 [0.6-1.1]	0.5 [0.3-6.9]	-	0.5 [0.3-6.9]	0.7 [0.5-1.0]	1	0.7 [0.5-1.0]
Severity (132)	17.0 [13.0-25.0]	22	17.5 [13.5-24.5]	10.0 [6.8-14.8]	-	10.0 [6.8-14.8]	15.5 [11.3-21.0]	22	<b>15.5 [11.3-21.0]<sup>e</sup></b>
PSDI (6)	1.8 [1.5-2.4]	1.7	1.7 [1.5-2.2]	2.0 [1.4-3.2]	-	2.0 [1.4-3.2]	1.8 [1.6-2.2]	1.7	1.8 [1.6-2.2]
<b>Cognitive Assessment</b>									
Orientation (5)	5.0 [4.5-5.0]	4	5.0 [4.0-5.0]	3.5 [1.5-5.0]	-	3.5 [1.5-5.0]	5.0 [4.0-5.0]	4	5.0 [4.0-5.0]
Immediate memory (15)	15.0 [13.5-15.0]	13	14.5 [13.0-15.0]	14.0 [10.5-15]	-	14.0 [10.5-15]	14.0 [13.3-15.0]	13	14.0 [13.3-15.0]
Concentration (5)	3.0 [2.0-3.0]	3	3.0 [2.0-3.0]	1.5 [0.8-3.0]	-	1.5 [0.8-3.0]	2.5 [2.0-3.0]	3	2.5 [2.0-3.0]
Delayed recall (5)	5.0 [3.5-5.0]	4	4.5 [3.8-5.0]	3.0 [1.5-5.0]	-	3.0 [1.5-5.0]	4.0 [3.3-5.0]	4	4.0 [3.3-5.0]
<b>SAC (30)</b>									
Total Score	26.0 [25.5-27.0]	24	26.0 [24.8-27.0]	22.0 [15.8-23.8]	-	22.0 [15.8-23.8]	25.5 [23.3-26.8]	24	25.5 [23.3-26.8]
<b>mBESS (30)</b>									
Total Score	26.0 [17.0-28.0]	20	23.0 [17.5-28.0]	22.0 [16.5-23.0]	-	22.0 [16.5-23.0]	22.0 [18.5-27.5]	20	22.0 [18.5-27.5]

IQR=inter-quartile range; SAC=Standardised Assessment of Concussion; mBESS=modified Balance Error Scoring System (hard surface only); GSI=Global Severity Index; PSDI=Positive Severity Distress Index; Numbers in ( ) are maximum score possible; \* =1 recurrent concussion in club based training and data reported are raw scores; Significant difference (p<0.05) than <sup>a</sup>=club; <sup>b</sup>=representative; <sup>c</sup>=new; <sup>d</sup>=recurrent; <sup>e</sup>=match related concussions; <sup>f</sup>=training related concussions.

of participation. Although not every playing position recorded at concussion at the club and zonal levels of participation, when combined every position recorded a concussion throughout the study duration, with the fullback sustaining the highest concussion incidence (49.2 per 1,000 match-hr). This contrast with professional rugby league [13], where the hooker records more concussions (48.2 per 1,000 match-hr) while the fullback (44.3 per 1,000 match-hr) records less. Consequently, backs recorded a higher incidence of concussion at the representative level of participation compared with forwards, but this was the opposite at the club level of participation. It is postulated these differences are related to match-play style however, further research could identify differences between club and representative match-play characteristics and concussion injury patterns.

The most frequent mechanism for a concussion occurring was during the tackle to the ball-carrier and most concussion injuries occurred in the fourth-quarter and second half of matches. This is similar to other studies [7-12] where the ball-carrier recorded more injuries than the tackler, however, there are no other studies reporting specifically on these aspects in direct relationship with concussion injuries in rugby league for comparison.

Finding that most identified concussions occurred without any loss-of-consciousness was not unexpected as only 8% to 9% of all concussions involve loss-of-consciousness [32,33]. Watching for signs of concussion during match-play and training can be challenging due to the heterogenous presentation of a player following a head impact. Being able to remove a player from activity and assess them

on the sideline is important in identifying pathognomonic signs and symptoms and reducing the risk of a worse clinical outcome [34]. It is essential team management are aware of the signs and symptoms that can occur and remove the player from the activity to enable a full assessment to be completed. All participants removed from rugby league activities within this study were required to complete a post-event SCAT and to be reviewed by a health practitioner to identify if a concussive injury occurred. Only those with a confirmed diagnosis of concussion were recorded in the database.

Reportedly, amateur rugby league players have lower skill levels and physiological attributes than semi-professional [35] and professional players, resulting in higher incidences of injuries at the lower levels of match-play. This may account for the higher incidence of concussions at the amateur level when compared with both semi-professional and professional levels of competition [14]. This may be similar for the identification of concussion when comparing professional sport with amateur sport. Although the SCAT guidelines utilised were adhered to throughout the study, the thresholds utilised in the current study differed from those reported for professional rugby union ([http://www.lnr.fr/IMG/pdf/IRB\\_HIA\\_2\\_EN.pdf](http://www.lnr.fr/IMG/pdf/IRB_HIA_2_EN.pdf)) and professional rugby league (<http://media.therfl.co.uk/docs/2016%20RFL%20Medical%20Standards%20final%20PDF.pdf> page 34). In rugby union, the Head Impact Assessment (HIA) incorporates sections of the SCAT-3 and identifies thresholds for the SAC as 24 or below, immediate memory as 12 or less, concentration as two or below and delayed recall as three or less. In rugby league the identification of a concussion with the SCAT-3 has a threshold for the SAC as 24 or below, concentration as two or below and delayed recall of three or less. The thresholds utilised in this study were similar to a previous study and in conjunction with the lower physiological attributes and skill-levels may account for the higher concussion incidence when compared with other levels of competition [35,36]. Further research is warranted in relation to threshold limits for concussion identification.

Inclusion of the symptom indices helped to identify the distress the concussed player was under. Interestingly, the indices increased with recurrent concussions and may indicate a cumulative effect of distress for those concussions that occur in a short (<1 yr) time frame [31]. Whilst the recovery period was not examined in this study, previous research suggests that participants with a repeat concussion in the same year take longer to return-to-play [37]. Further, participants with a previous concussion are 1.5 times more likely to have another concussion, while participants with a history of three or more concussions are 3.4 times more likely to record a subsequent concussion [33]. Concussion history questionnaires may help identify the players at risk, but these rely on participant honesty and knowledge of concussions. Future studies should consider conducting a longitudinal review of sports players including the symptoms indices utilised in the current study and incorporating recovery time, repeat concussion intervals, and differences in recovery time, for players with recurrent concussions in the same year against repeat concussions over the longitudinal period.

## Conclusions

Throughout the four-year study duration there were five concussions during trainings and 22 concussions in matches. Although not every playing position recorded a concussion at the club and zonal levels of participation, when combined every position recorded a concussion over the study duration, with the fullback

sustaining the highest concussion incidence. The most commonly identified mechanism for a concussion occurring was during the tackle to the ball-carrier and most concussion injuries occurred in the fourth-quarter and second half of matches. Future studies should consider a longitudinal review incorporating recovery time, repeat concussion intervals, and differences in recovery time, for players with recurrent concussions in the same year against repeat concussions over the longitudinal period.

## References

- Cummins C, Orr R. Analysis of physical collisions in elite national rugby league match play. *Int J Sports Physiol Perform.* 2015;10(6):732-9.
- Gabbett T. Incidence of injury in semi professional rugby league players. *Br J Sports Med.* 2003;37(1):36-44.
- Gabbett T. Influence of training and match intensity on injuries in rugby league. *J Sports Sci.* 2004; 22(5):409-17.
- Gabbett T, Godbolt R. Training injuries in professional rugby league. *J Strength Cond Res.* 2010; 24(7):1948-53.
- Gabbett T, Jenkins D, Abernethy B. Physical collisions and injury in professional rugby league match-play. *J Sci Med Sport.* 2011;14(3):210-5.
- Gardner A, Howell D, Levi C, Iverson G. Evidence of concussion signs in national rugby league match play: A video review and validation study. *Sports Med Open.* 2017;3(29):10.
- Gardner A, Iverson G, Levi C, Schofield P, Kay-Lambkin F, Kohler R, et al. A systematic review of concussion in rugby league. *Br J Sports Med.* 2015;49(8):495-8.
- Gardner AJ, Iverson GL, Quinn TN, Makdissi M, Levi CR, Shultz SR, et al. A preliminary video analysis of concussion in the national rugby league. *Brain Injury.* 2015;29(10):1182-5.
- Gissane C, Jennings D, Jennings S, White J, Kerr K. Physical collisions and injury rates in professional super league rugby, the demands of different player positions. *Clev Med J.* 2001;4:147-55.
- Gissane C, Jennings D, Standing P. Incidence of injury in rugby league football. *Physio.* 1993;79(5):305-10.
- Gissane C, Jennings D, White J, Cumine A. Injury in summer rugby league football: The experiences of one club. *Br J Sports Med.* 1998; 32(2):149-52.
- Guskiewicz K, McCrea M, Marshall S, Cantu RC, Randolph C, Barr W, et al. Cumulative effects associated with recurrent concussion in collegiate football players: The NCAA concussion study. *JAMA.* 2003;290(19):2549-55.
- Guskiewicz K, Register-Mihalik J, McCrory P, McCrea M, Johnston K, Makdissi M, et al. Evidence-based approach to revising the SCAT2: introducing the SCAT3. *Br J Sports Med.* 2013;47(5):289-93.
- Guskiewicz K, Weaver N, Padua D, Garrett W. Epidemiology of concussion in collegiate and high school football players. *Am J Sports Med.* 2000;28(5):643-50.
- Hänninen T, Parkkari J, Tuominen M, Iverson GL, Öhman J, Vartiainen M, et al. Interpreting change on the SCAT3 in professional ice hockey players. *J Sci Med Sport.* 2017;20(5):424-31.
- King D, Gabbett T. Training injuries in new zealand amateur rugby league players. *J Sci Med Sport.* 2008; 11(6):562-5.
- King D, Gabbett T, Gissane C, Hodgson L. Epidemiological studies of injuries in rugby league: Suggestions for definitions, data collection and reporting methods. *J Sci Med Sport.* 2009;12(1):12-9.
- King D, Gissane C. Injuries in amateur rugby league matches in new zealand: A comparison between a division one and a division two premier grade teams. *Clin J Sports Med.* 2009;19(4):277-81.

19. King D, Gissane C, Brughelli M, Hume P, Harawira J. Sport-related concussions in new zealand: A review of 10 years of accident compensation corporation moderate to severe claims and costs. *J Sci Med Sport*. 2014;17(3):250-5.
20. King D, Gissane C, Clark T. Concussion in amateur rugby league players in new zealand: A review of player concussion history. *NZ J Sports Med*. 2014;40(2):8-13.
21. King D, Gissane C, Clark T, Marshall S. The incidence of match and training injuries in rugby league: A pooled analysis of published studies. *Int J Sport Sci Coach*. 2014;9(2):417-31.
22. King D, Gissane C, Hume P, Flaws M. The king–devick test was useful in management of concussion in amateur rugby union and rugby league in new zealand. *J Neurol Sci*. 2015;351(1-2):58-64.
23. King D, Hume P, Clark T. First-aid and concussion knowledge of rugby league team management, administrators and officials in new zealand. *NZ J Sports Med*. 2010;37(2):52-68.
24. King D, Hume P, Gissane C, Clark T. Use of the king–devick test for sideline concussion screening in junior rugby league. *J Neurol Sci*. 2015;357(1-2):75-9.
25. King D, Hume P, Gissane C, Clark T. Semi-professional rugby league players have higher concussion risk than professional or amateur participants: A pooled analysis. *Sports Med*. 2017;47(2):197-205.
26. King D, Hume P, Milburn P, Gianotti S. Rugby league injuries in new zealand: A review of 8 years of accident compensation corporation injury entitlement claims and costs. *Br J Sports Med*. 2009;43(8):595-602.
27. King D, Hume P, Milburn P, Guttenbeil D. Match and training injuries in rugby league: A review of published studies. *Sports Med*. 2010; 40(2):163-78.
28. King T, Jenkins D, Gabbett T. A time-motion analysis of professional rugby league match-play. *J Sports Sci*. 2009;27(3):213-9.
29. McCrory P, Johnston K, Meeuwisse W, Aubry M, Cantu R, Dvorak, et al. Summary and agreement statement of the 2nd International Conference on Concussion in Sport, Prague 2004. *Br J Sports Med*. 2005;39(4):196-204.
30. McCrory P, Meeuwisse W, Aubry M, Cantu B, Dvorák J, Echemendia RJ, et al. Consensus statement on concussion in sport: The 4th international conference on concussion in sport held in zurich, november 2012. *Br J Sports Med*. 2013;47(5):250-8.
31. McCrory P, Meeuwisse W, Johnston K. Consensus statement on concussion in sport-the 3rd international conference on concussion in sport held in zurich, november 2008. *J Sci Med Sport*. 2009;12(3):340-51.
32. Meir R. Evaluating players' fitness in professional rugby league: Reducing subjectivity. *Strength Cond Coach*. 1993;1(4):11-7.
33. Merritt V, Meyer J, Arnett P. A novel approach to classifying post concussion symptoms: The application of a new framework to the post-concussion symptom scale. *J Clin Exp Neuropsych*. 2015;37(7):764-5.
34. Orchard J. Orchard sports injury classification system (OSICS). *Sport Health*. 1995;11(3):39-41.
35. Savage J, Hooke C, Orchard J, Parkinson R. The incidence of concussion in a professional australian rugby league team, 1998-2012. *J Sports Med*. 2013;7.
36. Shehata N, Wiley JP, Richea S, Benson BW, Duits L, Meeuwisse WH, et al. Sport concussion assessment tool: Baseline values for varsity collision sport athletes. *Br J Sports Med*. 2009;43(10):730-4.
37. Taubman B, McHugh J, Rosen F, Elci OU. Repeat concussion and recovery time in a primary care pediatric office. *J Child Neurol*. 2016;31(14):1607-10.