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REVIEW ARTICLE

Semi-Professional Rugby League Players have Higher Concussion Risk than Professional or Amateur Participants: A Pooled Analysis

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Abstract A combined estimate of injuries within a specific sport through pooled analysis provides more precise evidence and meaningful information about the sport, whilst controlling for between-study variation due to individual sub-cohort characteristics. The objective of this analysis was to review all published rugby league studies reporting injuries from match and training participation and report the pooled data estimates for rugby league concussion injury epidemiology. A systematic literature analysis of concussion in rugby league was performed on published studies from January 1990 to October 2015. Data were extracted and pooled from 25 studies that reported the number and incidence of concussions in rugby league match and training activities. Amateur rugby league players had the highest incidence of concussive injuries in match activities (19.1 per 1000 match hours) while semi-professional players had the highest incidence of concussive injuries in training activities (3.1 per 1000 training hours). This pooled analysis showed that, during match participation activities, amateur rugby league participants had a higher reported concussion injury rate than professional and semi-professional participants. Semi-professional participants had nearly a threefold greater concussion injury risk than amateur rugby league participants during match participation. They also had nearly a 600-fold greater concussion injury risk than professional rugby league participants during training participation.

Key Points

Semi-professional rugby league participants have a higher risk of concussions when compared with amateur and professional participants for both match and training activities.

Amateur rugby league participants have the highest concussion injury rate when compared with junior, semi-professional and professional participants.

There is a higher risk of a concussion during match participation when compared with training participation but this varies with the different participation levels.

There are no studies published reporting on training injuries for women and junior participants.

1 Background

Rugby league has a high incidence of injury, especially when compared with rugby union [1]. Injury incidence in rugby league increases with higher participation level [2]. In reviews of match and training injuries in rugby league [2, 3],

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match injuries varied from 1 [4] to 825 [2, 5] per 1000 match hours while training injuries ranged from 12.2 [6] to 106 [7] per 1000 training hours. These studies are limited by small sample sizes, few clubs or competitions, use of different injury definitions and methodological approaches and short study duration [8]. The generalisability of these individual studies for the identification of the injury incidence in rugby league is therefore restricted [9].

One strategy utilised [9, 10] is to combine the information provided by epidemiological studies into a single estimate [11], termed a pooled analysis [12]. Pooled analysis has been undertaken for professional rugby league studies [9] (40 injuries per 1000 player hours) and more recently [10] by pooling all the published studies reporting match and training injury incidence (148 per 1000 match hours and a training injury incidence of 12.6 per 1000 training hours) at all levels of participation in rugby league. There have been nine key findings from these previous studies [9, 10, 13]. (1) There was no difference between injury rates for first and reserve grade players [9]; (2) there were significant differences between injury rates for different sites of the body, with the lower limbs having the highest injury rate [9]; (3) there was a small but not significant risk of injury when playing as a forward compared with playing as a back [9]; (4) more concussions were recorded in amateur than professional (risk ratio [RR] 2.4 [95 % confidence interval (CI) 1.5–3.8]; $p = 0.0002$), semi-professional (RR 3.0 [95 % CI 1.8–5.1]; $p < 0.0001$) and junior (RR 2.5 [95 % CI 1.2–5.5]; $p = 0.0132$) studies [10]; (v) the lower limb was the most common injury recorded (5.7 [95 % CI 5.1–5.8] per 1000 training hours) for all studies reporting training sessions [10]; (6) there were more concussions recorded in semi-professional than amateur (RR 13.5 [95 % CI 4.2–43.9]; $p < 0.0001$) training session studies [10]; (7) the non-time-loss (NTL) match injury rate was 5.6 (95 % CI 5.0–6.4) times higher than the time-loss (TL) injury rate [13]; (8) lacerations to the head and neck accounted for 77 % (95 % CI 70–83) of all NTL lacerations [13]; and (9) NTL concussions accounted for 71 % (95 % CI 58–80) of all concussions [13].

A systematic qualitative review of concussions in rugby league [14] identified that the incidence of concussion varied widely from 0.0 to 40.0 per 1000 playing hours depending on the injury definition utilised (time loss vs no time loss). The incidence rates varied between match and training activities, playing positions and the season (winter vs summer) [14]. Of all concussive injuries, 29 % were associated with illegal match activities [14].

1.1 Objective of the Pooled Analysis

The purpose of this pooled analysis was to review all published rugby league studies reporting injuries from match and training participation and report the pooled data estimates for rugby league concussion injury epidemiology. In addition, this pooled analysis added estimates of concussion injury incidence for professional, semi-professional, amateur and junior levels of participation in both the match and training environments.

2 Methods

The methodology utilised in this pooled analysis was similar to previous pooled analysis studies reporting rugby league injuries [9, 10] and followed the steps as described by Friedenreich [11, 15]. An additional advantage of utilising a pooled analysis approach is that the same statistical model can be utilised with data from methodologically diverse studies [16].

2.1 Search Strategy for Identification of Studies

Searches of PubMed, CINAHL, Ovid, Scopus and SPORTDiscus™ databases were performed to identify studies published in English between 1990 and October 2015. The research databases provided access to sports-oriented and biomedical journals, serial publications, books, theses, conference papers and related research published since 1948. Terms used for the search of relevant research studies included rugby league, football, league; in combination with athletic injur* concuss*, sport* related concuss*, brain injur*, brain concussion, mild traumatic brain injury, mTBI, head injury, TBI and brain damage. The '*' symbol was used as a 'wildcard' in the search strategy. Searches were limited to 'English language' only. The references of all relevant articles were searched for further articles. All publications identified were initially screened by publication title and abstract to identify eligibility. In cases of discrepancies of eligibility, another author assessed the publication to screen for eligibility. All articles that met the inclusion criteria were entered in an EndNote X6.0.1 database.

2.2 Inclusion and Exclusion Criteria

To establish some control over heterogeneity of the studies [17], inclusion criteria were established. Published studies that reported the incidence of injury in rugby league match and training activities were collated and included in the analysis if they

1. reported the match or training time exposure enabling calculation of player time injury rates; and
2. reported concussions as a result of match or training injuries; and

3. there was more than one study reporting concussion injuries at the same participation level.

Studies were excluded from this review if it was identified that the publication

1. was unavailable in English; or
2. did not provide match or training exposure enabling calculation of player time rates; or
3. did not report on concussions that occurred as a result of match or training activities; or
4. combined male and female sex match or training exposure and did not differentiate; or
5. was a case study; or
6. was a meta-analysis or systematic review of rugby league injuries.

2.3 Procedures

All of the studies included in the pooled analysis were observational in design. Two reviewers extracted the study characteristics and numerical data and assessed the quality by adhering to the protocol for systematic review of observational studies, the Meta-analysis Of Observational Studies in Epidemiology (MOOSE) [17] (see Table 1). This approach enabled a more precise estimate of effects of influential factors and took into account confounding factors (participation level and age) and the heterogeneity of the studies [16].

A total of 8326 articles were initially identified using the identified search strategy. This consisted of 1069 studies identified in PubMed, 4920 in CINAHL, 679 in Ovid Medline, 486 in Scopus and 1172 in SPORTDiscus™ (see Fig. 1). Utilising the term 'football' in the search strategy resulted in over 7500 citations. These were related to non-rugby league studies and were excluded. Of the abstracts reviewed, 495 were not rugby-league related, five were self-reported injuries and ten were review articles. These were also excluded from the study. A total of 52 articles were reviewed resulting in 25 articles being included in the study.

2.4 Assessment of Publication Quality

All studies meeting the selection criteria were assessed for quality based on modified previously published checklists [17]. Heterogeneity of the studies included in the literature review was expected as there might be differences in the study design, population and outcomes [17]. Quality was described as the confidence that the design, conduct and analysis of the study minimised bias in the estimation of the factors associated with injury on the outcome measures [18]. Overall quality of the studies included in the pooled analysis was good (median 4.9/6.0; range 4–5) (see Electronic Supplementary Material, Table S1). Not all studies were prospective and no study had a blinded outcome.

2.5 Statistical Analysis

The data from the individual studies were combined in order to obtain more precise estimates of the rate of concussion using a fixed-effects model [9, 11]. By utilising the fixed-effects model it is assumed that the true exposure effect in each study is the same [11]. We tabulated the included studies, incorporating the study level of participation, the number of reported concussions and the exposure hours reported. The pooled calculation of the incidence of concussion was undertaken to report the incidence per 1000 h and 95 % confidence intervals [19]. To compare between injury rates, risk ratios were used. To test for significant difference, Chi-squared (2×) goodness-of-fit tests were utilised. Each concussion injury was treated as an independent event and the data were assumed to follow a Poisson distribution. All statistics were carried out using the SPSS (IBM SPSS Statistics for Windows, Version 22.0, Armonk, NY: IBM Corp) statistical software packages.

3 Results

3.1 Literature Review

Twenty-five studies met the inclusion criteria for this review (see Table 1). Five review studies [3, 9, 14, 20, 21] were included in the data collection but were not utilised for the pooled analysis. The studies selected for inclusion reported rugby league match [7, 13, 22–38] ($n = 19$) and training [7, 13, 39–42] ($n = 6$) concussion injuries within their datasets (see Table 1). Although one study [43] reported concussions, it did not report total match and training exposure hours. As a result, the incidence per 1000 h could not be calculated and the study was excluded from the pooled analysis. Data pertaining to the participation level were reviewed and the studies meeting the inclusion criteria were grouped into professional (including reserve grade and elite) [13, 22–27]; semi-professional (including sub-elite) [7, 28–30, 39, 40]; amateur [31–36, 41, 42] and junior [4, 37, 38]. One study [44] reported on an amateur rugby league sevens tournament and was included into the amateur group. The studies varied widely for the incidence of concussions in rugby league from 0.01 [13] per 1000 training hours to 27.2 [32] per 1000 match hours. This large variation may be related to the different methodologies and sampling methods used in the conducting of the studies [5, 14].

Table 1 Study, MOOSE scores, year of publication, country where research undertaken, level of participation, sex, match or training environment, number of concussions and concussion incidence rate per 1000 h with 95 % confidence intervals

Study	MOOSE score	Year	Country	Level	Sex	Match/training	Concussions (*n*)	IR/1000 h (95 % CI)
Gibbs [25]	5/6	1993	Australia	Professional	Male	Match	5	1.6 (0.7–3.8)
Stephenson et al. [22]	5/6	1996	England	Professional	Male	Match	35	8.1 (5.8–11.3)
Gissane et al. [24]	5/6	1998	England	Professional	Male	Match (summer)	8	14.0 (7.0–28.1)
Gissane et al. [24]	5/6	1998	England	Professional	Male	Match (winter)	1	2.5 (0.4–17.9)
Raftery et al. [4]	5/6	1999	Australia	Junior	Male	Match	20	0.8 (0.5–1.2)
Gissane et al. [23]	5/6	2003	England	Professional	Male	Match	18	3.7 (2.3–5.9)
Gabbett [39]	5/6	2004	Australia	Semi-professional	Male	Training	3	0.7 (0.2–2.3)
Gabbett [7]	5/6	2004	Australia	Semi-professional	Male	Match	1	1.0 (0.1–6.9)
Gabbett [7]	5/6	2004	Australia	Semi-professional	Male	Training	36	9.8 (7.1–13.6)
Gabbett [29]	5/6	2005	Australia	Semi-professional	Male	Match	27	13.1 (9.0–19.2)
Gabbett and Domrow [28]	5/6	2005	Australia	Semi-professional	Male	Match	10	3.0 (1.6–5.6)
King [38]	5/6	2006	New Zealand	Junior	Male	Match	5	14.7 (6.1–35.3)
King et al. [44]	5/6	2006	New Zealand	Amateur	Male	Match	1	6.5 (0.9–46.5)
King and Gabbett [31]	5/6	2007	New Zealand	Amateur	Female	Match	2	6.1 (1.5–24.3)
Gabbett and Domrow [40]	5/6	2007	Australia	Semi-professional	Male	Training	5	0.8 (0.3–1.9)
King and Gabbett [41]	5/6	2008	New Zealand	Amateur	Male	Training	1	0.7 (0.1–4.7)
Gabbett [37]	5/6	2008	Australia	Junior	Male	Match	5	4.6 (1.9–11.0)
King and Gissane [33]	5/6	2009	New Zealand	Amateur	Male	Match	16	16.8 (10.3–27.5)
King and Gabbett [32]	5/6	2009	New Zealand	Amateur	Male	Match	8	27.2 (13.6–54.4)
King and Gabbett [30]	5/6	2009	New Zealand	Semi-professional	Male	Match	14	6.0 (3.5–10.1)
King and Clark [35]	5/6	2012	New Zealand	Amateur	Male	Match	8	19.3 (9.6–38.5)
King et al. [34]	5/6	2012	New Zealand	Amateur	Male	Match	5	35.3 (14.7–84.9)
Gissane et al. [13]	4/6	2012	England	Professional	Male	Training	1	0.01 (0.00–0.02)
Gissane et al. [13]	4/6	2012	England	Professional	Male	Match	61	7.0 (5.5–9.0)
King et al. [26]	5/6	2012	Australia	Professional	Male	Match	10	12.0 (6.5–22.4)
King et al. [36]	5/6	2015	New Zealand	Amateur	Male	Match	8	24.4 (12.2–48.7)
Gardner et al. [27]	4/6	2015	Australia	Professional	Male	Match	20	14.8 (9.6–23.0)

CI confidence interval, *IR* incidence rate (related to either match or training exposure hours depending upon the study cohort), *MOOSE* Meta-Analysis and Systematic Reviews of Observational Studies, *Year* year of publication

Many of the identified studies did not include all the areas of interest for the pooled analysis. Specific information was extracted from individual studies on an 'as-required' basis throughout the analytical process. If there were fewer than two studies reporting on the same participation level, their data were excluded from the pooled

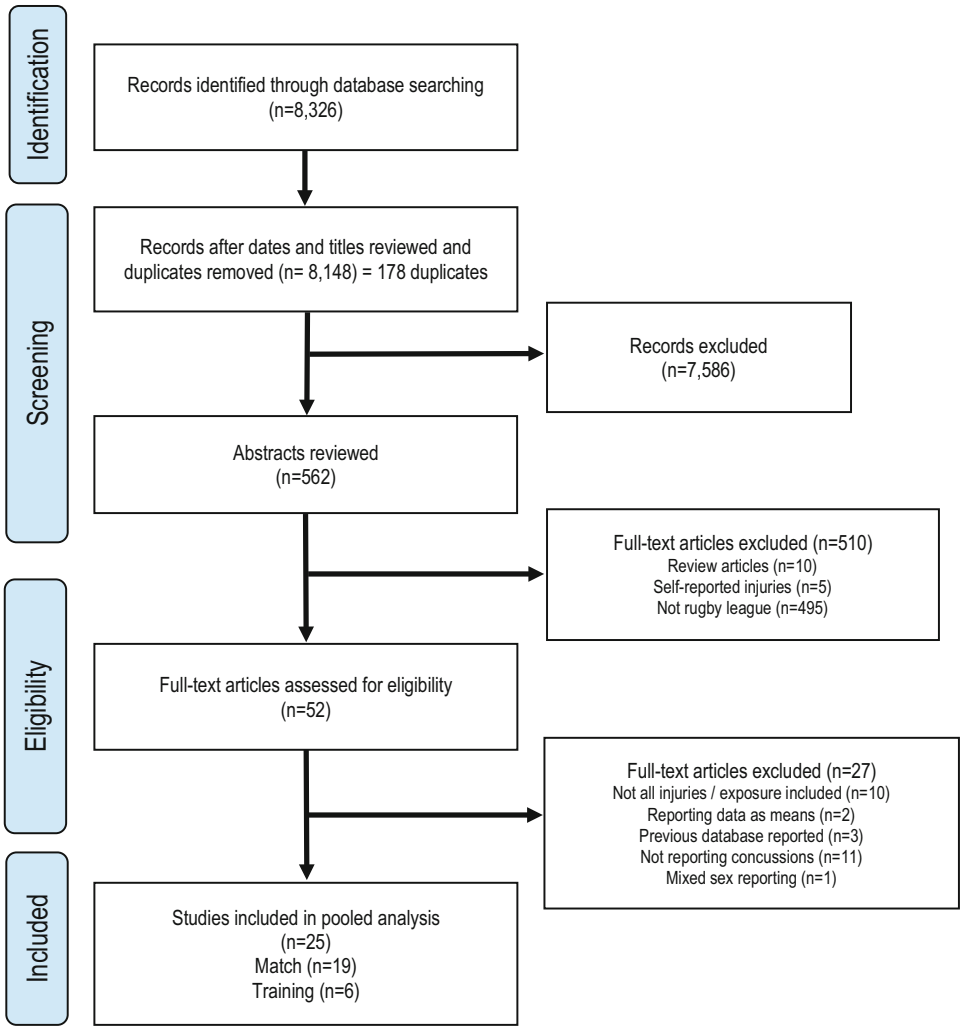

Fig. 1 Flow of identification, screening, eligibility and inclusion for the pooled analysis of match and training rugby league concussion injuries

analysis. Not all of the reviewed studies [1, 5, 6, 45–54] met the inclusion criteria of reporting concussions and this limited the evaluation of these to the total match and training injuries recorded.

3.2 Injury Exposure

The studies reporting match injury concussion data were drawn from 35,070 match exposure hours (professional: 22,246 match hours; semi-professional: 8780 match hours; amateur: 2612 match hours; junior: 1432 match hours) (see Table 2). Studies reporting training injury concussion data were drawn from 188,983 training exposure hours (professional: 161,701 training hours; semi-professional: 14,202 training hours; amateur: 13,080 training hours). There were no published studies that reported junior training injuries.

3.3 Concussion Injury Incidence

The pooled analysis concussion injury incidence for match injuries was 7.7 (95 % CI 6.8–8.7) per 1000 match hours (see Table 2). More concussions were recorded in amateur than professional (RR 2.7 [95 % CI 2.0–3.7]; $p < 0.0001$), semi-professional (RR 1.2 [95 % CI 0.9–1.6]; $p = 0.2552$) and junior (RR 1.0 [95 % CI 0.5–1.9]; $p = 0.9578$) match studies. The pooled analysis concussion incidence for training injuries was 0.3 (95 % CI 0.2–0.3) per 1000 training hours (see Table 2). There were more concussions recorded in semi-professional than amateur (RR 43.3 [95 % CI 4.5–416.7]; $p < 0.0001$) and professional (RR 585.5 [95 % CI 80.7–4249.3]; $p < 0.0001$) training session studies. Semi-professional rugby league participants recorded a twofold risk ratio (RR 1.9 [95 % CI 1.3–2.9]; $p = 0.0013$) when comparing match and training concussion incidence (see Table 3).

Table 2 Pooled analysis of concussions in rugby league for match and training exposure activities by participation level by number of concussions reported, total exposure hours and rate per 1000 h with 95 % confidence intervals

	Concussions (*n*)	Hours	Rate (95 % CI)
Match-reported concussions[a]			
Total	270	35,070	7.7 (6.8–8.7)
Sex			
Male [4, 7, 13, 22–26, 28–30, 32–35, 37, 38 44]	268	34,741.2	7.7 (6.8–8.7)
Female [31]	2	329.2	6.1 (1.5–24.3)
Level of participation			
Professional [13, 22–26]	158	22,246.2	7.1* (6.1–8.3)
Semi-professional [7, 28–30]	52	8779.9	5.9* (4.5–7.8)
Amateur [31–35, 44]	50	2611.8	19.1†,‡,§ (14.5–25.3)
Junior [4, 37, 38]	10	1432.5	7.0* (6.8–8.7)
Training-reported concussions[b]			
Total	48	188,983.0	0.3 (0.2–0.3)
Sex			
Male [7, 13, 39–42]	48	188,983.0	0.2 (0.2–0.3)
Level of participation			
Professional [13]	1	161,700.5	0.01§,* (0.00–0.04)
Semi-professional [7, 39, 40]	44	14,202.4	3.1‡,* (2.3–4.2)
Amateur [41, 42]	3	13,080.1	0.2‡,§ (0.1–0.7)

CI confidence interval

* $p < 0.05$ vs amateur

† $p < 0.05$ vs junior

‡ $p < 0.05$ vs professional

§ $p < 0.05$ vs semi-professional

[a] Rate reported per 1000 match hours

[b] Rate reported per 1000 training hours

Table 3 Risk ratio of match to training concussion injuries for total concussions, professional, semi-professional and amateur rugby league participants with 95 % confidence intervals

Participation level	RR (95 % CI)	χ^2 ($df = 1$)	*p* value
Total concussions [4, 7, 13, 22–41, 44]	30.3 (22.3–41.2)	1155.6	<0.0001
Professional [13, 22–27]	1148.5 (160.8–8203.4)	998.1	<0.0001
Semi-professional [7, 28–30, 39, 40]	1.9 (1.3–2.9)	10.36	0.0013
Amateur [4, 37, 38, 41, 42]	83.5 (26.1–267.4)	230.6	<0.0001

CI confidence interval, *df* degrees of freedom, *RR* risk ratio

4 Discussion

The aim of this review was to examine the incidence of concussion in rugby league match play and training, across all levels of play. While recent reviews [14, 55] have reported concussion incidence in rugby league, no pooled analysis providing more precise data has been undertaken until now [11]. The current pooled analysis encapsulates a broad spectrum of published rugby league studies and incorporates both match and training concussion injuries at professional, semi-professional, amateur and junior levels of participation. Studies reporting women's matches were limited to one study [31], and there were no published studies reporting on junior training rugby league injuries.

Our pooled analysis builds on three previous studies [9, 10, 13]. The major findings from our pooled analysis for studies of concussion occurring in match and training activities were (i) semi-professional participants had a

threefold greater concussion injury rate than amateur and nearly a twofold greater concussion injury rate than junior rugby league participants during match participation; and (ii) semi-professional participants had nearly a 600-fold higher concussion injury risk than professional participants, and nearly a 14-fold higher concussion injury risk than amateur rugby league participants during training participation.

It was not unexpected to find that professionals had a 1150-fold decrease and amateurs an 84-fold decrease in the incidence of concussion injuries occurring when comparing match and training injury incidence. In the case of professionals, this could be related to the higher number of training exposures they undertake, when compared with other levels of participation. While professional players may undertake more regular training sessions than amateurs, they likely moderate their training sessions so that injury does not limit their ability to appear in competition. Professional players have been reported to have higher skill levels and physiological attributes when compared with amateur and semi-professional players [5]. Amateur players partake in fewer regular training activities but rely on other employment as their source of income [41], so any injuries that occur may have a direct impact on their financial income. As a result, the number of training exposures would be fewer than semi-professional and professional participants, and the skill level is likely lower.

What was unexpected was the finding that semi-professional participants had a twofold decrease in the incidence of concussion when comparing the match and training injury incidence. Research suggests that semi-professional participants have superior physiological capabilities than amateur participants [5], producing a higher playing intensity that may result in a higher injury incidence [5, 22, 25, 56]. Semi-professional players have a mix of payment for playing and may also utilise another source of employment for income [5]. Over-exposure to a diverse range of physical activities may place them at a higher risk of injury such as concussion. The differences in the decrease in the incidence of concussion injuries may be a result of the approach to training activities at the different levels of participation. Further studies should explore the issues surrounding semi-professional players and the incidence of both match and training injuries, such as employment type, training hours and coaching styles and how these injuries can be reduced.

This pooled analysis showed that, in match activities, amateur rugby league participants had a higher reported concussion injury rate than professional and semi-professional participants. A limitation with using the pooled analysis for the identification of concussion injuries is that there are no data to further analyse where, when or what player positions are affected when the concussions occur during the match and training activities. Further studies could further explore the incidence of concussion injuries in all levels of rugby league participation and should include a more detailed analysis of the time, activity and player position to assist with injury prevention programmes.

The pooled analysis approach produces an overall estimate of the injuries recorded by combining the data provided by the selected studies [57]. As shown by this pooled analysis, the incidence of concussion in rugby league is 7.7 per 1000 match hours but this varies from 5.9 to 19.1 per 1000 match hours depending on the level of participation. The limitations with the use of a pooled analysis methodology have been previously described [11]. Issues such as differences in study design (observation vs self-reported injury) [58]; injury type, site and severity definitions; data collection methods and times; data recording medium and the maintenance of the data medium were considered and addressed through identification of the data used [9, 13]. An important issue in concussion injuries is the definition used [59]. Despite attempts to standardise the definition of concussion through the Concussion in Sports Group, there have been several variations produced [59]. As there is no universal definition of concussion, the incidence of concussion may be more than reported. Other factors that may influence the reporting of concussion are the knowledge of the people making the assessment, the availability of medical services to the team (as this will vary at the different participation levels) and the willingness of the player to report the signs of concussion [59]. Epidemiological studies conducted at the semi-professional and professional levels of participation involve medical personnel such as medical doctors and physiotherapists while amateur- and junior-level participation studies typically do not have these personnel available. The variability of the medical providers available at the sideline may also influence the assessment of concussion as what may be a concussion to one person may not be to another [60]. Despite these limitations, the strength of a pooled analysis is that it provides more accurate estimates of injury rates than the individual studies that provided the data [9]. It can be utilised as a comparison against other pooled studies and to obtain a combined estimator of the quantitative effect of the relative risk of injuries in rugby league match and training activities [11, 15].

5 Conclusion

The current pooled analysis examined a broad spectrum of published rugby league studies and incorporated both match and training concussion injuries at professional, semi-professional, amateur and junior levels of

participation. Our pooled analysis provided combined estimates of concussion injuries for training and games within rugby league and showed differences in concussion injury rates at several levels in the game. This pooled analysis showed that, during match participation activities, amateur rugby league participants had a higher reported concussion injury rate than professional and semi-professional participants. Semi-professional participants had nearly a threefold greater concussion injury risk than amateur rugby league participants during match participation. They also had nearly a 600-fold greater concussion injury risk than professional rugby league participants during training participation. Future studies could further explore the incidence of concussion injuries in all levels of rugby league participation and should include a more detailed analysis of the time, activity and player position to assist with injury prevention programmes.

Compliance with Ethical Standards

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Conflicts of interest Doug King, Patria Hume, Conor Gissane and Trevor Clark declare that they have no conflicts of interest relevant to the content of this review.

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