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Epidemiology of sport-related concussion rates in female contact/collision sport: a systematic review

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ABSTRACT

Objectives To determine sport-related concussion (SRC) incidence rates in female contact/collision sport.

Design Systematic review following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines.

Data sources Four databases (PubMed, SportsDiscus, Web of Science, CINAHL) were searched for data from 2012 to 2021.

Eligibility criteria Studies reporting SRC incidence rates or the number of concussions and athletic exposures (AEs) per 1000 participating events or hours in healthy female contact and collision sport athletes of any age were included.

Results The search yielded 8438 non-duplicate articles. Following screening, 19 were included in the analysis (median quality score=70%), with 8 reporting match or training incidence rates. Studies were primarily from US high school and collegiate populations; data are reported for eight sports. Rugby union reported the highest match SRC rates (8.2–16.11 per 1000 AE hours), followed by Gaelic football (5.21 per 1000 AE hours) and soccer (2.08–4.04 per 1000 AE events). Where available, match SRC rates were substantially higher than training and overall SRC rates.

Conclusion Female sports such as rugby union, Gaelic football and soccer present the highest risk for SRCs within the available data. Previous research indicates a potentially greater injury burden for female athletes experiencing SRCs than their male counterparts. Thus, future research should analyse concussion knowledge and return-to-play protocols in these sports. Future research should also prioritise exploration of the gap in SRC rates within amateur sports, and data should be presented specifically in the context of athletic exposures (match vs training).

Trial registration number CRD42021281569.

WHAT IS ALREADY KNOWN?

⇒ Sport-related concussions (SRCs) are common in contact/collision sports.

⇒ Female athletes can experience a greater injury burden from SRCs than males.

⇒ Untreated/undiagnosed SRCs can have a negative impact on an athlete's health.

WHAT ARE THE NEW FINDINGS?

⇒ Female rugby union, soccer and Gaelic football experience the highest SRC rates.

⇒ SRCs are much more likely to occur in match settings.

⇒ Future research should report match and training incidence and exposure data to adequately reflect true SRC risks in athletes.

INTRODUCTION

Consistent successful efforts are being made to close the sex gap in sports participation,[1] although the challenge of closing the sex gap in sports science research requires much greater efforts.[2] The act of increasing sports participation in all forms, especially in community settings, is a net positive for the physical, mental and social health of society[3] and should be encouraged to offset an increase in sedentary lifestyle–related diseases such as obesity and its associated comorbidities.[4] However, it is the responsibility of all key stakeholders to ensure that increased participation in female sports does not come at an increased risk to the well-being of athletes. Threats to athlete health, such as sport-related concussions (SRCs), must be addressed to avoid a parallel increase in risk as participation increases.

The 2017 Concussion in Sport Group defines sport-related concussion as a "mild traumatic brain injury (mTBI) induced by biomechanical forces transmitted either by a direct blow to the head or elsewhere in the body whereby an impulsive force can be transmitted toward the head".[5 6] By this definition, contact and collision sports represent a high degree of risk for SRCs. Collision sports are defined as sports in which routine, purposeful body-to-body collisions (eg, rugby union) are a legal and expected part of the game. In contrast, contact sports are defined as sports in which body-to-body contact occurs as part of the game, but purposeful body-to-body collisions are not allowed (eg, soccer).[7] Sport contact classifications are important in concussion research as they can be linked to the odds of sustaining an SRC.[8]

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Experiencing an isolated SRC does not appear to pose serious health risks if managed appropriately. Best practice steps include (1) immediate removal from play if a suspected SRC occurs, (2) performing an SRC screening using a validated tool such as the Sports Concussion Assessment Tool 5 (SCAT5) by an appropriate health professional and (3) following the outlined return to play (RTP) protocol for the sport in question.[5] However, research is beginning to suggest that female athletes may be at greater risk of sustaining an SRC, may take longer to recover in contact sports and may have more severe symptomology than male athletes.[9 10] Data regarding female athletes and SRCs are limited, but if this is true then current RTP protocols (step 3 above) may not be enough to protect these athletes; this is particularly relevant for female athletes in sports which may pose a higher risk for SRCs. This can also be challenging when organisations have specific timeframes for concussion recovery.[11–13]

In countries such as Ireland, there are various plans to increase female participation in sports. However, each of these plans does not refer to the medical support services these athletes should have access to.[14 15] Without trained allied medical professionals such as physiotherapists, athletic trainers or general practitioners available—applying the aforementioned key risk mitigation steps becomes much more difficult when treating SRCs. This issue extends to the elite level, where a recent study of female soccer athletes competing at the World Cup found that 33% of players did not have a dedicated physiotherapist within their domestic club, while 40% did not have a team physician.[16]

With this in mind, the following systematic review describes the current SRC rates in female contact/collision sports and which athletic groups are most at risk for SRCs. It is hypothesised that soccer, rugby union and Gaelic football will have the highest rates of SRCs, and it is intended that this study will guide future research into concussion knowledge and education and exploration of RTP protocols in female contact/collision sports.

METHODOLOGY

A stringent protocol was developed to adhere to The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[17] This study was also registered on the International Prospective Register of Systematic Reviews (PROSPERO) before commencing the literature search (CRD42021281569).

Literature search

Searches were performed on 22 September 2021 across four databases using Endnote V.20 (CINAHL, SportsDiscus, PubMed, Web of Science). Search terms were developed in three individual phases. In phase 1, potential terms and synonyms were tested in various databases. In phase 2, search terms were refined, and new terms were included if they improved the quality of results. In phase 3, an agreement was reached between AW/ED/LR on 16 September 2021 on the final search terms and databases to be included. The included search terms are as follows: Female OR Females OR Women OR Woman OR Ladies OR Girls **AND** Concussion OR Brain Injur* OR Head Injur* OR Athletic Injur* OR “Sports Concussion” OR “Sport-Related Concussion” OR “Mild Traumatic Brain Injury” OR mTBI OR TBI OR “craniocerebral trauma” OR “brain damage” **AND** Incidence OR Epidemiolog* OR Descriptive OR Overview OR Classification OR “Numerical Data” OR Exposure **AND** Sport OR Sports OR Athlete OR Athletes OR Athletics.

Inclusion/exclusion criteria

Original studies were to be included if they (1) reported data from 2012 to 2021, this was to align with the 4th Concussion Consensus Statement[18]; (2) written in English; (3) contained healthy female contact/collision athletes of any age and (4) contained SRC/mTBI incidence rates or contained the raw data needed to calculate an incidence rate.

Studies were to be excluded if (1) the study population was general population, clinical population, former athletes or military personnel; (2) concussion data were from reported histories, self-reporting or non-medical diagnosis; (3) the concussion was moderate, severe or unspecified TBI; (4) exposures were estimated; (5) the data were unextractable or did not contain the necessary data to calculate SRC rates; and (6) the study was graded as low quality.

Selection and screening of studies

Three independent researchers were involved in the screening process. AW first screened titles and abstracts for inclusion/exclusion criteria (phases 1 and 2). Before commencing each phase, a random sample of studies (5%) was sent to LR and ED to check for consistency in the application of criteria. At each stage, researchers were blinded to the coding of other research team members. The consensus was then reached by all members where disagreements occurred

Coding was performed in Endnote when excluding articles using the ‘Research Notes’ function. If it was unclear from the title (phase 1) or abstract (phase 2) whether the study was to be included or excluded, the study was assessed at the next stage of the cycle to determine whether it met the inclusion/exclusion point in question. In the third phase, full papers were screened for inclusion, and those that met all criteria had their data extracted. Where articles were not readily available, authors were contacted for article access. In the third phase, included systematic reviews were also handsearched for papers which may warrant inclusion.

Data extraction

Extraction was performed by one author (AW). The data extraction tool created can be found in online supplemental file. An agreement was reached between each member of the research team on the extraction template, and extractions were cross-referenced with original data by LR/ED.

Data were extracted regarding study design, setting, population, exposure type, the database used, length of observation, type of diagnosis (physiotherapist/athletic trainer/medical), diagnosis tool, number of concussions, AEs and SRC rates. An AE event is participation in any training or competition event regardless of duration. In contrast, an AE hour is the duration of participation in any training or competition events.

Numerical SRC rates were extracted where possible for match, training and overall SRC rates. Where the number of concussions and exposures were available, or where the number of injuries and per cent concussions were available—the following equation was used: SRC rate = (Σ concussions/(Σ exposures/1000)). If SRC rates from multiple years were reported, they were pooled into a singular SRC rate using a summation of AEs and SRCs, which were entered into the equation above. Where this could not be achieved, means±SD were calculated using the individual rates reported for each year.

Web Plot Digitizer V.4.5 (Automeris, San Francisco, CA, USA) was also used to extract SRC rates from figures when numerical values were not provided. Where necessary, primary authors were contacted via email to obtain additional information (number of concussions or exposures) to calculate SRC rates. Sample sizes, number of concussions and 95% CIs have been included where they have been reported.

Quality assessment/risk of bias

Levels of evidence were determined using the National Health and Medical Research Council recommendations.[19] A quality tool was adapted from a recent systematic review on concussion incidence in sports[20]; this tool specifically focuses on the risk of bias with respect to concussion incidence data. The tool contains 10 questions regarding study quality and concussion incidence reporting. Each question is scored with a potential maximum overall score of 20. Summary scores were converted to percentages for grading. Scores of ≥70% were regarded as high quality, 50–69% moderate quality and <50% low quality.

Data synthesis

Data were processed using Microsoft Excel 2019 (Microsoft, Redmond, WA, USA). Rate ratios (RRs) were calculated to quantify the SRC risk comparison between match and training where applicable. A meta-analysis was not performed for several reasons, including heterogeneity in the data and an inability to pool results due to a lack of contexts within the reported data, such as 95% CIs, sample sizes and sub-group-specific concussion data.

RESULTS

The literature search identified 11 053 articles, and 2615 duplicate records were removed immediately. The screening process can be viewed in figure 1. Ten studies appeared to meet all inclusion criteria but used an exposure estimate and thus were excluded.[21–30]

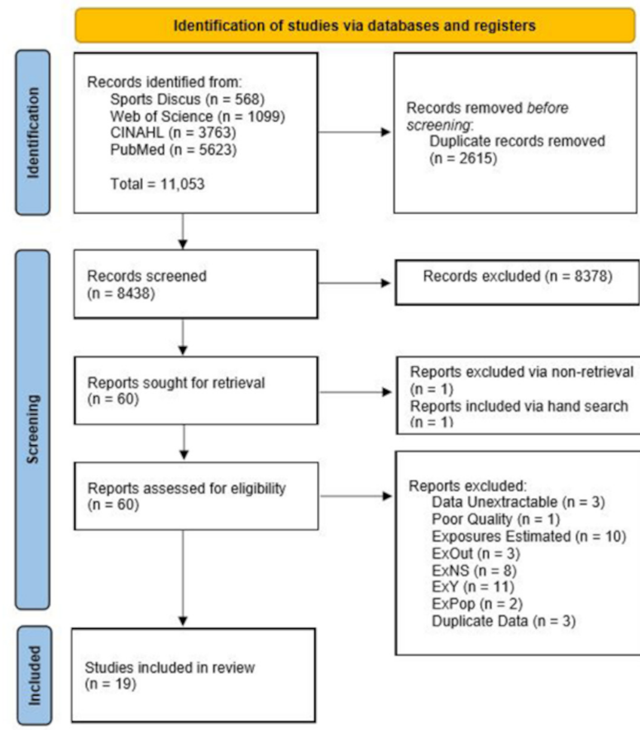

Figure 1 PRISMA flow diagram.

Characteristics of studies

Of the included studies, SRC incidence data were available for eight sports; nine for soccer,[31–40] five for basketball,[33–35 40 41] three for rugby union,[31 42 43] four for lacrosse,[34 35 44 45] two for camogie,[31 46] two for Gaelic football,[31 47] three for field hockey[34 35 48] and two for ice hockey.[35 49] These athletes competed at collegiate,[31 35 36 41 42 45 47–49] high-school,[32 34 37–40 44] middle-school,[33] amateur[43] and inter-county (elite) levels.[46] Eight (42.1%) of the included studies contained female-only athletic populations.[36 41 43 45–49]

Studies were predominantly from the USA,[32–41 44 45 48 49] with the remainder from the UK,[42] New Zealand[43] and Ireland.[31 46 47] Only four studies stated the diagnosis tool used, with these being the King-Devick,[43] SCAT2 and SCAT3,[35] and the SCAT3 alone.[33 39] In the US studies, the High-School Reporting Information Online (HS-RIO)[32 34 37 38 40 44] or the NCAA Injury Surveillance Program (NCAA-ISP)[36 41 45 48 49] was responsible for the majority of the data available. No tools were reported in these studies with a broad spectrum of reporting sources. However, the NCAA-ISP states it does not provide a definition of concussion and relies on the medical expertise of the medical professionals supplying data. The ATs are also encouraged to follow the definition of the Consensus statement on concussion in sport.[5 50] The NCAA concussion protocol outline is available here (https://www.ncaa.org/sport-science-institute/topics/concussion-safety-protocol-template).

Table 1 Overview of studies reporting SRC rates in female contact/collision sport athletes

	LOE—quality score	Sport	Population	Time period	Rate available
Armstrong and Greig 2018[42]	II—55%	Rugby union	Collegiate (UK)	N/A	Overall
Bretzin *et al* 2021[45]	III—80%	Lacrosse	Collegiate (US)	2014–2019	Overall
Buckley and Blake 2018[46]	II—55%	Camogie	Inter-county (IE)	2016	Match
Chandran *et al* 2021[49]	III—75%	Ice hockey	Collegiate (US)	2014–2019	Overall
Chandran *et al* 2021[36]	III—75%	Soccer	Collegiate (US)	2014–2019	Overall
Comstock *et al* 2015[37]	III—80%	Soccer	High school (US)	2012–2014	Match vs training
Comstock *et al* 2020[44]	III—70%	Lacrosse	High school (US)	2012–2019	Overall
Kerr *et al* 2017[33]	II—65%	Basketball	Middle school (US)	2015–2016 (1)	Match vs training
		Soccer			
Kerr *et al* 2019[34]	III—80%	Soccer	High school (US)	2013–2018	Match vs training
		Basketball			
		Lacrosse			
		Field Hockey			
Kerr *et al* 2019[38]	III—80%	Soccer	High school (US)	2012–2016	Match vs training
Teahan *et al* 2021[31]	II—60%	Gaelic football	Collegiate (IE)	N/A	Match vs training
		Camogie			Match
		Rugby union			Match
Khodae *et al* 2017[32]	III—70%	Soccer	High school (US)	2012–2014	Overall
King *et al* 2020[43]	II—90%	Rugby union	Amateur (NZ)	2018–2019 (2)	Match vs training
Lempke *et al* 2021[41]	III—70%	Basketball	Collegiate (US)	2014–2019	Overall
McGuine *et al* 2019[39]	II—85%	Soccer	High school (US)	2016–2018	Overall
Nedimyer *et al* 2021[48]	III—65%	Field hockey	Collegiate (US)	2014–2019	Overall
O'Connor *et al* 2020[47]	II—50%	Gaelic football	Collegiate (IE)	N/A	Overall
Putukian *et al* 2019[35]	II—75%	Soccer	Collegiate (US)	2013–2018	Match vs training
		Lacrosse			
		Ice hockey			
		Field hockey			
		Basketball			
Schallmo *et al* 2017[40]	III—65%	Basketball	High school (US)	2012–2015	Overall
		Soccer			

IE, Ireland; NZ, New Zealand; UK, United Kingdom; US, United States of America.

Overall, 29 seasons of data were collected for soccer, 22 for lacrosse, 19 for basketball, 15 for field hockey, 10 for ice hockey, 4 for rugby, 3 for field hockey and Gaelic football, and 1 season and 1 championship competition were recorded in camogie. An overview of included studies, demographics and quality assessment are available in table 1. Figure 2 presents SRC rates by type and sport, while table 2 compares the overall match and training SRC rates by sport—only eight studies reported such context-specific data.[31 33–35 37 38 43 46]

Study quality

Twelve studies were graded as high quality,[32 34–39 41 43–45 49] while seven were graded as moderate quality.[31 33 42 46–48] One study was excluded for poor quality.[51] The primary methodological issues were (1) not providing descriptive statistics and sample sizes, (2) not obtaining medical injury histories or stating such, that is, if previous SRCs were sustained, and (3) not stating the diagnosis tool used.

Concussion incidence in Gaelic Athletics Association (GAA)

Sports within the GAA are high-intensity field sports indigenous to Ireland. These sports represent some of the most popular sports in Ireland but are played globally in over 70 countries. There are over 200 000 registered female Gaelic footballers and 100 000 camogie players worldwide.[52 53]

Two studies of female Gaelic football were reported from the same collegiate institution.[31 47] Between the

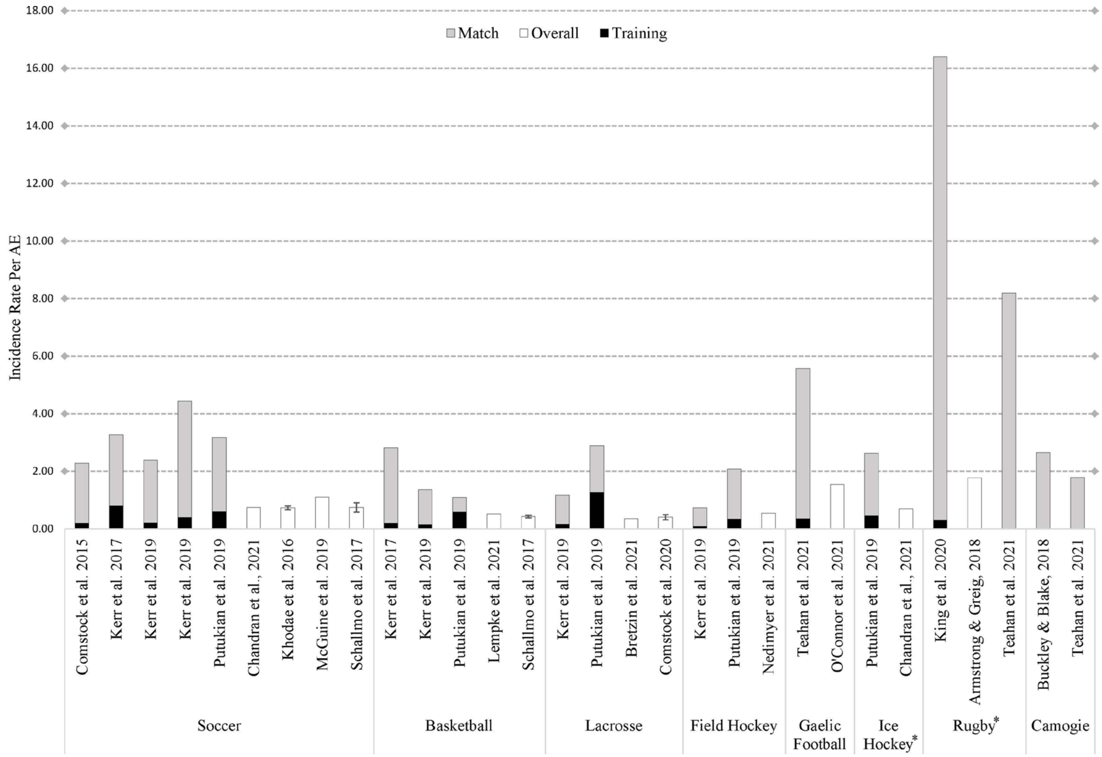

Figure 2 Overall SRC rates graph. Match, training and overall SRC rates by sport and AE type, reported by included studies. SDs are presented where individual rates were reported for each year of data collection (*indicates collision sport). AE, athletic exposure; SRC, sport-related concussion.

studies, 251 athletes were involved in 7885.82 AE hours and sustained 11 concussions. A match rate of 5.21 was reported in one study, with a training rate of 0.36 per 1000 AE hours[31]; however, match exposures were quite low (576 AE hours). An overall SRC rate of 1.54 per 1000 AE hours was reported by the other study.[47]

In comparison, two studies reported data for camogie in 147 collegiate and inter-county (elite) GAA athletes totalling 4619 (match=938) AE hours and two diagnosed concussions (both in match play). Match rates of 1.79[31] and 2.65 per 1000 AE hours[46] were reported in these studies. No training rate exists as no SRCs were reported in training exposures.

Concussion incidence in rugby union

Rugby union reported the highest concussion rate of all included sports.[31 42 43] In total, 163 athletes competed in 6343.45 AE hours, revealing 14 diagnosed concussions. Match rates of 8.2[31] per 1000 AE hours were reported in Irish collegiate athletes, while a higher rate of 16.11 (95% CI 8.4 to 31)[43] per 1000 AE hours was reported in amateur New Zealand athletes, with the latter also reporting a training rate of 0.3 (95% CI 0.0 to 2.1) per 1000 AE hours. An overall SRC rate of 1.77 per 1000 AE hours was found in English collegiate athletes.[42]

Concussion incidence in stick sports

Ice hockey reported a match SRC rate of 2.17 per 1000 AE events, with a training rate of 0.45 per 1000 AE events.[35] An overall of 0.70 per 1000 AE events was also reported in one study.[35 49] Within field hockey, the match SRC rates were 0.65 and 1.74 per 1000 AE events for high school[34] and collegiate athletes,[35] with training rates of 0.09 and 0.34 per 1000 AE events. The overall rate for collegiate athletes was 0.54 per 1000 AE events.[48]

Lacrosse data were available for two collegiate[35 45] and two high school[34 44] populations. High school match rates for lacrosse were 1.0 per 1000 AE events, with a training rate of 0.17 per 1000 AE events.[34] The collegiate match rate was 1.62 per 1000 AE events, with a much higher training rate of 1.27 per 1000 AE events than any other training rate reported in this review.[35] Overall SRC rates for high school athletes were 0.41±0.09[44] per 1000 AE events, while an overall SRC rate of 0.36 per 1000 AE events was reported in a collegiate population.[45]

Concussion incidence in basketball

Match SRC rates were higher than the training rate in middle school (2.61 vs 0.2 per 1000 AE events),[33] with similar findings reported for high school athletes (1.21 vs 0.16 per 1000 AE events).[34] However, in collegiate athletes, this was not the case (0.50 vs 0.59 per 1000 AE events).[35] Overall SRC rates in high school basketball were 0.43±0.05 per 1000 AE events,[40] with a similar rate of 0.52 per 1000 AE events found in collegiate athletes.[41]

Concussion incidence in soccer

Nine studies reported SRC data for female soccer across middle school, high school and collegiate populations. Match versus training SRC rates for middle-school

Table 2 SRC rates and rate ratios (RRs) reported by included studies

Sport	Paper	Match (95% CI)	Training (95% CI)	Overall (SD)	AE units	RR
Soccer	Comstock *et al* 2015[37]	2.08	0.20	–	Events	10.67
	Kerr *et al* 2017[33]	2.47	0.8	–		3.09
	Kerr *et al* 2019[34]	2.18	0.214	–		10.19
	Kerr *et al* 2019[38]	4.04	0.4	–		10.10
	Chandran *et al* 2021[36]	–	–	0.75		–
	Khodae *et al* 2016[32]	–	–	0.73 (±0.07)		–
	McGuine *et al* 2019[39]	–	–	1.1		–
	Schallmo *et al* 2017[40]	–	–	0.75 (±0.16)		–
	Putukian *et al* 2019[35]	2.57	0.6	–		4.28
Basketball	Kerr *et al* 2017[33]	2.61	0.2	–	Events	13.05
	Schallmo *et al* 2017[40]	–	–	0.43 (±0.05)		–
	Lempke *et al* 2021[41]	–	–	0.52		–
	Kerr *et al* 2019[34]	1.21	0.155	–		7.81
	Putukian *et al* 2019[35]	0.5	0.59	–		0.85
Lacrosse	Kerr *et al* 2019[34]	1	0.166	–	Events	6.02
	Comstock *et al* 2020[44]	–	–	0.41 (±0.09)		–
	Bretzin *et al* 2021[45]	–	–	0.358		–
	Putukian *et al* 2019[35]	1.62	1.27	–		1.28
Field hockey	Kerr *et al* 2019[34]	0.65	0.087	–	Events	7.47
	Putukian *et al* 2019[35]	1.74	0.34	–		5.12
	Nedimyer *et al* 2021[48]	–	–	0.54		–
Gaelic football	Teahan *et al* 2021[31]	5.21	0.36	–	Hours	14.47
	O'Connor *et al* 2020[47]	–	–	1.54		–
Ice hockey	Putukian *et al* 2019[35]	2.17	0.45	–	Events	4.82
	Chandran *et al* 2021[49]			0.7		
Rugby union	King *et al* 2020[43]	16.11 (8.4 to 31)	0.3 (0.0 to 2.1)	–	Hours	53.70
	Armstrong and Greig 2018[42]	–	–	1.77		–
	Teahan *et al* 2021[31]	8.2	–	–		–
Camogie	Teahan *et al* 2021[31]	1.79	–	–	Hours	–
	Buckley and Blake 2018[46]	2.65	–	–		–

SRC, sport-related concussion.

athletes were 2.47 versus 0.8 per 1000 AE events.[33] High school rates were 4.04 versus 0.4,[38] 2.18 versus 0.8[34] and 2.08±0.31 versus 0.20±0.04[37] per 1000 AE events, while collegiate SRC rates were 2.57 versus 0.6 per 1000 AE events.[35]

Overall, SRC rates were much lower as one high school study reported a 2-year average of 0.73±0.07 per 1000 AE events,[32] while the only included randomised control trial reported a rate of 1.1 per 1000 AE events in high school athletes.[39] Another study reported a 3-year average of 0.75±0.16 per 1000 AE events in high school athletes,[40] and in collegiate athletes, the rates reported for one five-season study was 0.75 per 1000 AE events.[36]

DISCUSSION

The following study aimed to determine the SRC incidence rates in female contact/collision sports. Rugby union recorded the highest SRC rates for collision sports, while soccer and Gaelic football recorded the highest rates for contact sports. A meta-analysis was not feasible due to data heterogeneity and a lack of contextualisation within the data. These challenges are discussed later. Rates are presented for eight sports (figure 2), primarily in high school and collegiate populations, with limited data available on amateur and elite athletes. In elite sports, injury surveillance tends to be decentralised by the club, particularly outside the USA, which may limit its entry into the published literature.

In amateur and youth settings, a lack of medical support becomes a limiting factor to successful injury surveillance.[54]

It was hypothesised that the highest SRC rates would exist in female rugby union, Gaelic football and soccer. This was evident in the data collected as match SRC rates ranged from 8.2 to 16.11 (95% CI 8.4 to 31) per 1000 AE hours in rugby union[31 42 43] and 5.21 per 1000 AE hours in Gaelic football,[31 47] with the range in soccer reported to be 2.08–4.04 per 1000 AE events (see figure 2).[32–40] This review is the first to report SRC rates for the sport of camogie. Interestingly, its match SRC rates mimic that of a high-risk sport such as soccer (1.79–2.65 per 1000 AE hours). However, the sport has only two diagnosed SRCs in the current literature. A key finding of this study was that in almost all instances, match SRC rates were much higher than training rates (see table 2) which is consistent with the previous literature.[20] Presenting overall SRC rates was deemed necessary to capture all available epidemiological data in a sparse territory for female athletes involved in contact/collision sports. However, this was only done if a context-specific alternative could not be calculated. Figure 2 highlights how match versus training rates can provide a much better reflection of the likely SRC rates within a given sport, and both researchers and practitioners should not interpret overall SRC rates as reliable predictors of athlete risk.[55]

Potential role of sex in the epidemiology of sport-related concussion

It has been previously stated that female athletes are twice as likely to experience an SRC in the same sport as males. These athletes are also more likely to experience more severe symptoms and can take longer to recover.[9] NCAA-ISP studies which replicated our included studies in male soccer, basketball, ice hockey and lacrosse found only soccer posed a notably higher overall SRC risk for females.[56–59] However, one US collegiate study found higher match SRC rates for females than males in each of these sports.[35] A systematic review of SRCs in team contact sports also reported far lower match rates for male rugby union (2.16–8.93 per 1000 AE hours) than reported for females in the current study.[20] Soccer was the sport with the most studies reporting female SRC data (n=9), although with 13.3 million registered soccer players worldwide,[60] the increased risk of SRCs requires a specific focus in future research.

The likelihood to self-report an SRC may have a role in the higher SRC rates in female sports,[61–63] but much more is unclear regarding biomechanical and neurophysiological factors at play. Divergence in systemic inflammation and symptom severity between sexes,[64] and sex-specific cognitive dysfunction and impairment that is 1.7 times greater in females following an SRC have been suggested as potential mechanisms for increased injury burden.[65] Recovery times are prolonged,[66 67] and female athletes may also be more at risk for post-concussive syndrome.[68]

Limitations of systematic review protocol and reviewed literature

Three limitations of the study design are as follows: the broad search string that returned too many irrelevant results, the requirement to update data inclusion to 2012–2021 to reflect the SRC climate and the need to retrospectively exclude exposure estimations for quality control.

Only the US provides longitudinal data for this study, originating from the US HS-RIO and NCAA ISP databases, two structures with well-documented methodologies.[69 70] Most countries do not have concussion-specific laws like the USA.[71] Therefore, the current study cannot be generalisable internationally as it does not account for the complexity of decentralisation, policy and cultural factors affecting the epidemiology of SRCs.[54 72] Recent research has highlighted such issues with poor adherence to consensus guidelines for SRC assessments in Canadian and Irish athletic therapists. The latter reported two domain and three domain assessment minimums rates (symptomology, balance, neurocognition etc) of 38.6% and 3.5%, respectively, which may lead to false negatives in SRC screening. In addition, it was also found that Irish athletes may also have a role in their RTP clearance which should not be endorsed considering athletes may display poor attitudes towards SRCs.[73] The injury surveillance systems listed previously have been shown to lack access to sports without medical support staff.[54] This issue is also a likely contributor to a major limitation within all non-US data included in this study, that is, Gaelic football, camogie and rugby union, which have extremely limited data available to report on in terms of both exposures and diagnosed SRCs. Considering the findings within athletic therapists mentioned previously where educated medical care is provided, athletes with no such medical support should be an important focus for future research.

Finally, heterogeneity poses another limitation within the included studies. This can occur through data pooling from up to 100 sources in the NCAA-ISP/HS-RIO through different exposure units (AE events vs hours). At the same time, pooling of data may also not be advised as, in many cases, the ratio of match to training exposures is not known,[20] a factor which greatly affects the reported SRC rate.

Implications for practice

Female sport, particularly amateur female sport, does not have the financial and physical resources that the male game does. In sports where females are more likely to sustain an SRC, this can create severe implications for athletes, particularly in SRC assessment in obtaining the necessary guidance and support during the RTP process.[73]

As previously mentioned, insufficient monitoring and support systems are currently available when SRCs do occur. An investigation into rugby unions in Irish schools found that only 28% of athletes had access to physiotherapy while 14% had access to a doctor if injured.

In addition, 31% of schools did not implement formal injury prevention measures.[74] One study in amateur GAA clubs found that 31% of clubs do not report head injuries of underage athletes to parents/guardians, only 42% of coaches accessed online concussion education material, and 15.8% of clubs did not follow RTP protocols.[75]

Qualitative studies have also highlighted that female athletes in such sports are prone to non-disclosure and may even compete with a suspected SRC.[76 77] Although coaches have a meaningful role in the reporting culture within their team, research on GAA coaches identified only 10% of coaches discussed concussion management and safety with their athletes. There was a significant reported difference (p<0.05) when coaches had received formal education compared with those who did not,[75] which is an avenue for future research. Unpublished qualitative data from AW in coaches and allied healthcare professionals have found a severe lack of first aid, allied medical support and knowledge around RTP in female sports, particularly for adolescent female athletes. This is also paired with financial, cultural and educational barriers between current consensus,[5] best practices and current procedures. These contextual and socioecological factors (infrastructure, levels of care) have been observed to impact injury and perceptions of such, even at elite levels of the sport.[78 79]

The current study has highlighted a higher risk of SRCs in sports such as rugby union and Gaelic football. This is worrying and may have implications for the welfare of female athletes participating in these sports. It should be stated, however, that the reported SRC rates included from the sports discussed earlier should be interpreted with caution as the number of diagnosed concussions and AE events or hours are very small for these studies, which again is likely related to the lack of medical support staff in female sport emphasised throughout this study.[31 42 43 46 47] One system which may aid in overcoming the implications of the decentralised surveillance systems which exist outside of the USA is the introduction of concussion passports which have been suggested as a future tool which can be easily implemented worldwide to aid in protecting athletes post-concussion and throughout their playing careers.[80]

This is the first systematic review identifying SRC data in female Gaelic athletes. However, sports within the GAA may have several flaws which affect SRC rates, irrespective of sex. An internal injury database analysis reported male general head injury rates of 0.26 per 1000 AE hours of Gaelic football and 0.19 per 1000 AE hours of hurling (the male version of camogie).[81] It is likely that there is an under-reporting of concussions within these data, a qualitative trend now being explored in retired athletes in other sports.[82] A study of GAA athletes of both sexes found a decreased likelihood of reporting an SRC when the importance of competition increased. The study also found that 50.4% of athletes may not report an SRC to avoid letting teammates down, while 40.7% would not want to let their friends/community down.[83]

Video analysis of male Gaelic football and hurling found a high rate of athletes returning to play without assessment following PCEs (potential concussion events) despite the GAA adopting the advice from the 5th Concussion Consensus statement.[5] Two-season analyses of both sports found a removal rate of 7.1% and 5.0% for hurling and Gaelic football, respectively. This study also found that 25/182 players experiencing a PCE returned to play without any assessment, while most assessments were under 1 min.[84] These practices, along with the high SRC rates found in ladies' Gaelic football and camogie and the low levels of data collection in our study, highlight a gap in the literature that should be addressed by future research.

To conclude, we have a long way to go in fully understanding the depth, complexity and long-term consequences of SRCs. We also have a long way to go to understand the complexity of SRC assessment, monitoring and cultural factors affecting SRC attitudes. This is especially relevant for female athletes in sports such as rugby union, soccer and Gaelic football, where SRC rates are highest. Therefore, more research is required to overcome all barriers between SRC diagnosis and management systems in female contact and collision sport athletes.

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