Title: Significant difference in injury and concussion rates in female and male youth rugby: A step towards targeted prevention strategies

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Abstract: **(250/250)**

Objectives: To examine differences in match and training injury and concussion rates in female and male Canadian high school rugby players. **Methods**: A two-year prospective cohort study was completed in a high school rugby league (n=361 females, 421 player-seasons; n=429 males, 481 player-seasons) in Calgary, Canada over the 2018 and 2019 playing seasons. Baseline testing was completed at the start of each season and injury surveillance and individual-level player exposure hours were tracked for the duration of the season. Injury incidence rates (IR) and incidence rate ratios (IRR) were estimated using Poisson regression, offset by player exposure hours and clustered by team. **Results:** Match IR for females was 62% higher than males (IRR=1.62, 95% CI 1.20-2.18) and the training IR was 2-fold higher for females (IRR=2.15, 95% CI 1.40-3.32). The female match concussion IR was 70% higher than the males (IRR=1.70, 95% CI 1.08-2.69).

The tackle accounted for 70% of female and 65% of male match injuries. Females had a 75% greater tackle-related IR compared with males (IRR=1.75, 95% CI 1.20-2.56). Additionally, female tacklers had a two-fold greater rate of injury compared with male tacklers (IRR=2.17, 95% CI 1.14-4.14). Previous playing experience was not associated with tackle-related injury or concussion IRs. **Conclusion:** The rate of injury and concussion was significantly higher in females within this Canadian high school cohort. This emphasizes the need for development, implementation, and evaluation of female-specific injury and concussion prevention strategies to reduce injury and concussion in female youth rugby addressing a gap in the literature.

Key messages:

- *What is already known about this topic*:
    - Youth rugby injury and concussion rates are high.
- *What this study adds*:

- In this cohort, Canadian female youth high school rugby players have a 62% higher injury and 70 % higher concussion rate than males.
- There were no differences in tackle-related injury or concussion rates when stratified by previous playing experience, suggesting previous experience is not a protective factor against tackle related injury or concussion.

- *How this study might affect research, practice, or policy*:
  - Based on the observed cohort, sex-specific prevention strategies targeting injury and concussion are needed and experience does not have an association with tackle-related injury.
  - Implications for age at which contact, including the tackle, is introduced should be considered to increase sport safety for youth rugby players.

Introduction

Rugby is a collision team sport, played globally by nearly 8 million people (1). In Canadian adolescents, rugby participation rates are rising, even with the disruption caused by the COVID-19 pandemic and with some provinces seeing increased rates above pre-pandemic participation (2). Although these participation rates are promising for fostering the sport in Canada, injury incidence rates (IR) and concussion IRs specifically have previously been reported to be higher than other youth sports (3). To date, epidemiological studies examining injury and concussion in youth rugby has been focused on the male game. Furthermore, very few studies have compared male and female IRs. Of those that have been published, evidence from Canada (4) and the UK (5) suggest that females may have higher IRs than their male counterparts. In New Zealand, insurance claims data suggest that females were less likely to register a claim than their male counterparts (at the 5-6, 7-12, 13-17 and 18-20 age groups) (6) and in a U19 rugby-7s tournament context in the USA, Lopez et al. (7) reported no significant differences between male and female players. Given the high proportion of these injuries in youth rugby (male and female) associated with the tackle event, the link between tackle proficiency and injury has been explored with some suggestion better tackle technique may be associated with a lower injury risk (8). Given tackle proficiency could be associated with previous playing experience, there has been speculation that previous playing experience could be associated with lower IRs. However, few studies have investigated this relationship with Archbold et al (9) finding no difference between players who started playing before they were 10 years old compared with those who started after this time.

Given the health burden associated with the assessment and treatment on both the athletes and the healthcare system, the need for injury prevention strategies is apparent. To date, the focus of prevention strategies has been on the male youth game, including neuromuscular training programs

(10, 11), equipment use (9, 12-14) and policy change (15). A further understanding of differences between male and female injury and concussion IRs and event-specific IRs is required to ensure adequate allocation of resources to prevention strategies in the future. Therefore, the objectives of this study were to examine differences in injury and concussion IRs as well as event-specific injury and concussion IRs between male and female youth rugby players. A secondary objective was to examine the association between previous rugby playing experience and tackle-related injury and concussion IRs.

Methods

A two-year prospective cohort study was used to complete injury surveillance over the 2018 and 2019 high school rugby seasons in Calgary, Alberta, Canada. The methods for the present study have been previously reported (4). This study was part of a larger cohort study (Surveillance in High Schools and Community Sport to Reduce Injuries and Concussions—SHRed Injuries—REB17-1948) and pilot study for the (Surveillance in High Schools and Community Sport to Reduce Concussions and their Consequences – SHRed Concussions – REB18-2107) program.

Participants

High schools from the Calgary Senior High School Athletics Association (CSHSAA) were invited to participate in the rugby injury surveillance study. CSHSAA includes both male and female rugby leagues. The male league consists of a junior and senior age-level, where the junior level is divided into Division 1 and Division 2 and the senior age-level is divided into Division 1, 2, and 3. The female league consisted of a junior and senior age-level, where the junior level was only one division and the senior age-level had Divisions 1, 2, and 3. The junior leagues consisted of Grade 10 and 11 (age 15-16) players. The senior leagues consisted of Grade 11 and 12 (age 16-18) players. If schools only had one team, players in Grades 10, 11, and 12 would be on the same

team and compete at the senior level. During both years of the study, the league had a 13-week playing season (Pre-season: Year 1 – 7 weeks, Year 2 – 5 weeks; Regular season: Year 1 – 4 weeks, Year 2 – 6 weeks; Playoffs: Year 1 – 2 weeks, Year 2 – 2 weeks).

Procedure

The injury surveillance methodology used was previously validated in youth sport (16). Surveillance was completed using REDCap (Research Electronic Data Capture) (17) in the first year of the study and Athlete Monitoring (FITSTATS Technologies Inc) during the second year (18). Prior to every season, a pre-season baseline testing session was completed for each team that agreed to take part in the study. Participants completed baseline questionnaires and a research assistant-administered Sport Concussion Assessment Tool-5 (SCAT5). Experience was captured based on participant self-report through baseline questionnaires including the number of previous playing years and type of previous playing experience (*e.g.,* school, club, regional, provincial, national). Individual match and training session attendance was prospectively collected by a nominated team designate (*e.g.*, sports medicine student, coach, player, team manager) on paper or electronic weekly exposure sheets.

Weekly team visits were made by a study therapist and research assistant to collect all injury details. Study therapists assessed participant injuries. In the event of a suspected concussion, participants were referred to a study sport medicine physician at the University of Calgary Sports Medicine Centre or partner community clinic. When an injury occurred, an injury report form (IRF) was completed to obtain all injury location, type, mechanism, medical attention, and return-to-play information. All injuries were validated by a study certified athletic therapist or physiotherapist. All concussions were referred to a study sports medicine physician and followed the 5th Concussion Consensus Statement (19). Injury definitions used included time-loss, medical

attention, and a "SHRed" study definition. The "SHRed" study definition was the primary definition used and included any injury that required medical attention and/or included time-loss and/or the inability to complete a session.

Statistical analyses

Stata SE v.14 was used to complete all analyses (20). All baseline player demographics were reported using medians and ranges or proportions. Injury IRs and injury incidence rate ratios (IRR) with 95% confidence intervals (95% CI) were estimated using a Poisson regression analysis offset by player match and training exposure hours and clustered by team to examine RRs comparing male and female IRs by injury definition. The a-priori alpha value was set at 0.05. Males were considered the reference group for all comparisons. To compare tackler and ball-carrier IR, similar Poisson regression analyses were employed; however, each injury throughout the season was considered independent in the model, regardless of how many injuries an individual had sustained.

Equity, diversity, and inclusion

The author group consisted of five female and three male researchers at differing career stages with various backgrounds (i.e., epidemiologist, sport medicine physician, physiotherapist, athletic therapist). Our study included both male and female participants. Sex was accounted for in the analysis.

Table 1. Player demographics

		Females (n=421)	Males (n=481)
Year of participation (n)	2018	214	225
	2019	207	256
	Missing	0	0
Age (years)	Median (range)	16.6 (15.1-18.4)	16.7 (14.7-19.1)
	Missing	2	5
Grade (n[%])	10	146 (35)	171 (36)
	11	158 (38)	165 (35)
	12	117 (28)	142 (30)
	Missing	0	3
Height (cm)	Median (range)	165.1 (147.3-185.4)	180.3 (152.4-198.1)
	Missing	10	15
Weight (kg)	Median (range)	60.8 (43.7-110.3)	72.6 (45.4-146.3)
	Missing	12	12
Concussion in the past 12 months (n[%])	Yes	67 (17)	61 (13)
	No	320 (83)	413 (87)
	Missing	34	23
Non-concussive injury in past 12 months (n [%])	Yes	131 (34)	107 (23)
	No	256 (66)	351 (77)
	Missing	34	23
Rugby playing experience (n[%])	No previous playing experience	174 (43)	197 (42)
	1-year previous playing experience	180 (45)	213 (46)
	2-years or greater of previous playing experience	50 (12)	58 (12)
	Missing	17	13
Playing position (n[%])	Forward	199 (52)	239 (51)
	Back	181 (48)	233 (49)
	Missing	41	9
Team playing division (n[%])	Junior Division 1	55 (13)	92 (19)
	Junior Division 2	0** (0)	122 (25)
	Senior Division 1	86 (21)	142 (30)
	Senior Division 2	188 (46)	76 (16)
	Senior Division 3	80 (20)	49 (10)
	Other	12***	0
	Missing	0	0

* 52 males and 60 females were repeat participants across the two study years.
**No division available in the female league
***One team was not a part of the CSHSAA and solely competed at exhibition 7s tournaments

Results

In Year 1, 8/24 schools that participated in the CSHSAA who had high school rugby teams were invited to participate in the study. Schools were invited based on convenience sampling methods, where those closest to the University of Calgary Sports Medicine Centre were invited first. Fifteen teams from six schools agreed to participate. In Year 2, 10/25 schools were invited, of which 17 teams from eight schools agreed to participate.

A total of 902 player-seasons (female n=421; male n=481;) were recorded over the course of the 2018 and 2019 high school rugby season from 32 unique teams (female N=14; male N=18,). Sixty females and 52 male players participated in both study years. Player demographics are reported in Table 1.

Injury and concussion

Four-hundred and twenty-nine injuries (female 240; male 189) were recorded in 42,414 player-hours (female 17,713; male 24,701). One-hundred-fifty-five female and 134 male match injuries were reported. One injury was reported by 272 players (128 males and 144 females) and multiple injuries were reported by 73 players(2 injuries reported by 23 males and 40 females, 3 injuries reported by 5 males and 4females, and 4 injuries reported by 1 female). Match and training injury counts, IRs, and IRRs by injury definition are reported in Table 2. Females had a 62% significantly higher overall match injury IR (IRR=1.62, 95% CI: 1.20-2.18) and greater than 2-fold higher overall training injury IR (IRR=2.15, 95% CI:1.40-3.32) than males. Concussion was the most common match injury type for females (40%) and males (38%). Females had a 70% higher match concussion IR (IRR=1.70; 95% CI: 1.08-2.69) than males.

Table 2. Matching and training injury counts, rates, and IRR by injury definition

Injury definition	Sex	# injuries	IR	IRR (95% CI)
		Match		
"SHRed"	Female	155	93.7 (78.6-111.7)	**1.62 (1.20-2.18)***
	Male	134	57.9 (45.4-73.8)	1
Time-loss	Female	121	73.1 (61.2-86.7)	**1.51 (1.12-2.04)***
	Male	122	48.4 (37.7-62.0)	1
Medical attention	Female	119	71.9 (58.5-88.5)	**1.75 (1.24-2.48)***
	Male	95	41.0 (30.9-54.4)	1
Concussion	Female	62	37.5 (26.8-52.3)	**1.70 (1.08-2.69)***
	Male	51	22.0 (15.9-30.4)	1
		Training		
"SHRed"	Female	85	5.3 (4.0-6.9)	**2.15 (1.40-3.32)***
	Male	55	2.5 (1.7-3.5)	1
Time-loss	Female	61	3.8 (2.7-5.4)	**2.02 (1.17-3.50)***
	Male	42	1.9 (1.2-2.9)	1
Medical attention	Female	58	3.6 (2.8-4.6)	**2.07 (1.42-3.03)***
	Male	39	1.7 (1.3-2.4)	1
Concussion	Female	16	1.0 (0.7-1.4)	1.72 (0.78-3.79)
	Male	13	0.6 (0.3-1.2)	1

** p-value<0.05*

Mechanism of injury and concussion

The tackle was the event associated with the greatest number of match and training injuries for females [109 match injuries (70%); 37 training injuries (44%)] and males [87 match injuries (65%); 26 training injuries (58%)]. Table 3 and 4 present match and training tackle-related, IRs, and mechanisms. Table 3 displays IRs and IRRs by the "SHRed" injury definition for all

mechanisms of injury, but only include the top two mechanisms for concussion due to a low concussion count across other mechanisms.

Females had 1.75-fold higher tackle-related match injury IR (IRR=1.75, 95% CI 1.20-2.56) and 1.76-fold higher tackle-related concussion IR (IRR=1.76, 95% CI 1.04-2.97) compared with males (Table 3). Additionally, the female tackler-specific injury IR was two-fold that of their male counterparts (IRR=2.17, 95% CI 1.14-4.14; Table 2). For both females and males, the rate of injury to the tackler compared to the ball-carrier did not differ (Females: IRR=1.02, 95% CI 0.89-1.20; Males: IRR=0.83, 95% CI 0.60-1.15).

Table 3. Match mechanism of injury and concussion by "SHRed" injury definition

Mechanism of injury	Sex	# injuries [proportion of all injuries (%)]	IR (95% CI)	IRR (95% CI)
All injury				
All tackle	Female	109 (70)	65.9 (51.8-83.9)	**1.75 (1.20-2.56)****
	Male	87 (65)	37.6 (27.8-50.7)	1
Ball-carrier	Female	47 (30)	28.4 (20.3-39.8)	1.40 (0.92-2.13)
	Male	47 (35)	20.3 (15.6-26.4)	1
Tackler	Female	62 (40)	37.5 (27.1-51.8)	**2.17 (1.14-4.14)****
	Male	40 (30)	17.3 (9.8-30.5)	1
Ruck/Maul	Female	12 (8)	7.2 (3.5-14.8)	0.93 (0.41-2.14)
	Male	18 (13)	7.8 (5.0-12.2)	1
Scrum	Female	7 (5)	4.2 (1.8-10.1)	2.45 (0.60-10.1)
	Male	4 (3)	1.7 (0.5-5.4)	1
Running	Female	4 (3)	2.4 (1.1-5.4)	0.80 (0.30-2.30)
	Male	7 (5)	3.0 (1.4-6.21)	1
Other contact***	Female	9 (6)	5.4 (3.2-9.3)	2.10 (0.80-5.5)
	Male	6 (4)	2.5 (1.1-5.9)	1
Other non-contact****	Female	4	2.4 (0.1-7.6)	-
	Male	0 (0)	-	-
Overuse	Female	6 (4)	3.6 (1.3-10.8)	1.40 (0.35-5.54)
	Male	6 (4)	2.6 (1.0-6.6)	1
Unknown	Female	4 (3)	-	-
	Male	6 (4)	-	-
Concussion***				
All tackle	Female	49 (79)	29.6 (20.3-43.1)	**1.76 (1.04-2.97)****
	Male	39 (76)	16.8 (11.5-24.6)	1.0
Ball-carrier-specific	Female	19 (31)	11.4 (7.0-19.0)	1.27 (0.63-2.54)
	Male	21 (41)	9.1 (5.5-14.9)	1.0
Tackler-specific	Female	30 (48)	18.1 (11.5-28.6)	2.33 (0.98-5.53)
	Male	18 (35)	7.8 (3.4-16.4)	1.0

** "SHRed" injury definition: "any injury that required medical attention and/or included time-loss and/or the inability to complete a session.*
***Statistically significant difference given the 95%CI does not include the null of 1 or p-value<0.05*
**** Other contact: collision, unspecified*
*****Other non-contact: change in speed, unspecified*

*****Concussion IRs and IRRs are only listed for the top two mechanisms due to limited number of concussions occurring across all reported mechanisms. Mechanisms not listed include ruck, scrum, and other or unspecified contact-related mechanisms.*

Table 4. Training tackle injury and concussion comparison by "SHRed" injury definition*

Mechanism of injury	Sex	# injuries (proportion of all injuries [%])	IR (95% CI)	IRR (95% CI)
All injury				
All tackle	Female	37 (44)	2.3 (1.5-3.5)	**1.98 (1.06-3.71)****
	Male	26 (47)	1.2 (0.7-1.9)	1
Ball-carrier-related	Female	17 (20)	1.1 (0.7-1.7)	**3.39 (1.08-10.57)****
	Male	7 (13)	0.3 (0.1-0.9)	1
Tackler-related	Female	20 (24)	1.2 (0.7-2.4)	1.47 (0.66-3.28)
	Male	19 (35)	0.8 (0.5-1.4)	1
Concussion				
All tackle	Female	11 (69)	0.7 (0.4-1.1)	1.92 (0.81-4.54)
	Male	8 (62)	0.4 (0.2-0.8)	1
Ball-carrier-related	Female	7 (44)	0.4 (0.2-0.8)	**4.88 (1.22-19.46)****
	Male	2 (15)	0.1 (0.02-0.3)	1
Tackler-related	Female	4 (25)	0.2 (0.1-0.6)	0.93 (0.28-3.10)
	Male	6 (46)	0.3 (0.1-0.7)	1

** "SHRed" injury definition: "any injury that required medical attention and/or included time-loss and/or the inability to complete a session.*
***Statistically significant difference given the 95%CI does not include the null of 1 or p-value<0.05*

Previous playing experience

There were no differences found by level of experience for tackle-related injury or concussion IRs for females or males (Figure 1). When dichotomized into tackler-specific and ball carrier-specific injury and concussion IRs (Figure 2), there were no differences in tackle-related IRs found by player experience.

[insert Figure 1]

[insert Figure 2

Discussion

The aim of this study was to compare injury and concussion IRs between female and male youth rugby players, using common injury surveillance methods and to investigate differences in IRs by mechanisms of injury. Irrespective of the injury definition used, all injury and concussion IRs specifically were significantly higher in female players. Although the tackle represented the most injurious match event for females and males, female players had a higher rate of tackle-related injury than males. This difference was driven by injuries to the tackler in matches and injuries to the ball carrier in training. This study demonstrates the need for further evaluation of timeline for introduction of the tackle in games, tackle technique, and tackle proficiency in youth rugby, particularly in females.

The current evidence base for sex-specific comparisons in youth rugby is limited to a small number of studies that use a range of injury definitions [e.g. time loss (4, 5), medical attention (4, 7) and medical insurance claims (6)], and are from different contexts [e.g. 7-a-side (7) vs 15-a-side (4, 5). Therefore, it is unclear if the conflicting findings between these studies are due to differences in methodology, or a genuine context-specific risk based on sex. The data presented in this study suggest that injury and concussion IRs are higher in a female high school population in Canada

compared with males. This aligns with the work of Barden et al, (5) which uses similar methodology and injury definitions to the study presented here. However our findings do not align with that of Quarrie et al, (6), where insurance claim data were used. Previously, lack of playing experience in female cohorts (4) and sex-specific increased risk of specific injury types (e.g., anterior cruciate ligament, concussion)(5) have been suggested as a potential rationale for this increased risk in a female population. Further investigation, including high quality risk factor studies, are required to understand these differences.

The tackle has been widely documented as the match event associated with the highest injury and concussion IRs (4, 21, 22). Consistent with these findings, this study found 70% of female and 65% of male match injuries were tackle-related. Tackle-related injury rates in females were significantly higher than those of males. This is particularly evident in the case of tackler-specific injuries and concussions in matches (~2-fold higher IR) and ball carrier-specific IRs in training (~3-fold higher IR). When considering the introduction of the tackle to the sport, it is often speculated and anecdotally reported that an early introduction to contact is beneficial to learn the skills required, while the physicality and level of impact is still low. In this study, both the male and female cohorts reported low levels of experience with only 12% in each group having played for 2 or more years and ~40% having never played the sport on entry to the study. While the narrative documenting the need for early exposure to contact, such as tackling, has been anecdotally suggested, there is limited evidence supporting player experience as a risk factor with Archbold et al (9) reporting no differences in overall injury risk in school boy rugby when considering playing experience for those who began playing before or after 10 years of age. To consider how this might affect contact components of the sport, one could consider the sport of ice

hockey where Eliason et al, (23) reported no protective effect of body checking experience on injury and concussion risk.

In the context of this study, player experience was not found to have a protective effect in reducing injury or concussion IRs in the tackle overall or for tacklers and ball carriers specifically. This finding was supported in both the female and male cohorts and may be an important consideration for governing bodies when deciding the age to introduce contact. While the age of introduction of contact currently varies between countries, other considerations to the safe introduction to contact might include tackle training (e.g. World Rugby Tackle Ready (24)) and a graded introduction to contact over a period of time (e.g. 6-weeks (25)). While policies and guidance around the age of introduction of contact may be helpful in community environments, further research should be undertaken to investigate the tackle characteristics associated with injury and concussion in a youth context, as has been done in the male professional game (26, 27). With concerns rising surrounding the potential long-term effect of exposure to repetitive head contacts and concussions, the age of introduction of contact may be an area of exploration to minimize head impacts and concussion in youth players. This is, to the authors' knowledge, the first-time number of years of previous player experience specifically has been shown in the rugby literature to not protect against injury or concussion and, therefore, further empirical evidence should be examined to support this finding.

Limitations associated with this study include the lack of generalizability to other rugby environments. While this sample is representative of the high school population in Calgary, the findings across other contexts may differ. While clustering by team was possible in our analyses, we were unable to consider cluster at an individual level for players participating in both study years due to small numbers participating in both years (n=112 [60 females, 52 males] players participating in both years of the study) and thus each year was treated independently for these

players. This study has demonstrated that in the context of Canadian youth rugby players, there are differences in injury and concussion IRs and tackle-specific IRs within female and male leagues. As gender was not identified specifically across both years in this study, we were unable to examine gender and only highlight sex differences. This study emphasizes the need for further evaluation and targeting of prevention strategies focused on the female game specifically, given the focus on the male game to date (10, 11). Importantly, future studies should consider sex and gender differences and how they relate to injury risk to identify higher injury risk individuals and develop targeted injury prevention strategies for all. Furthermore, a significant finding is the lack of protective effect that player experience has on tackle related injury risk, thus suggesting early exposure to tackling does not protect against injury and concussion.

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Contributions

KJS, BEH, JPW, CAE, and AMB contributed to study proposal development. AMB led all components of data collection, cleaning, and management. IJS, SWW, SS, KJS, JPW, and AMB contributed to data collection, entry, and cleaning. IJS, SWW, BEH, CAE, and AMB contributed

to data analysis and interpretation of study results. CAE led acquisition of funding and study design. All authors critically reviewed the manuscript for submission.

Competing interests and funding

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Patient and Public Involvement

Rugby Canada and Alberta High School Athletics were involved as knowledge brokers in contributing to discussion regarding study design, study recruitment, injury surveillance methods, and dissemination of research findings within the rugby and school communities. The research questions were also informed by the priorities, experience, and preferences of engaged knowledge brokers within school and rugby organizations. Players, team designates and coaches were dedicated to the collection of weekly exposure data, identification of a player with a suspected concussion, and supporting communication with the research team for injury follow-up. Preliminary study findings have been discussed with partners from Rugby Canada, Provincial Rugby Associations, and Alberta High School Athletics.

Data sharing

We do not have a data sharing agreement.

Ethical approval

Ethical approval for this study was obtained through the Conjoint Health Research Ethics Board at the University of Calgary (REB17-1948 and REB18-2107) and the participating school boards (*i.e.,* Calgary Board of Education, and Calgary Catholic School District).

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