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Do Female University Varsity Athletes Have a Greater Risk of Injury Within a Competitive Varsity Season?

AIDAN K. COMEAU†1, ERIC C. PARENT‡2, and MICHAEL D. KENNEDY‡1

[1]College of Health Sciences, Faculty of Kinesiology, Sport, and Recreation, University of Alberta, Edmonton, ALBERTA, CANADA; [2]College of Health Sciences, Department of Physical Therapy, University of Alberta, Edmonton, ALBERTA, CANADA

†Denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 16(6): 129-147, 2023. Previous varsity sport injury research has analyzed how acute and chronic injury severity, type, and location differs between sport and sexes, with limited research in time to injury. Canadian university varsity sport injury research is especially sparse and mostly retrospective. Thus, we aimed to understand injury differences in male and female competitive university athletes competing in the same sport. Athletes who competed on the basketball, volleyball, soccer, ice hockey, football (male), rugby (female), and wrestling teams were eligible for the study. There were 182 male and 113 female athletes who provided informed consent to be prospectively followed over a season. Injury date, type, location, chronicity, and events missed due to injury were recorded on a weekly basis. Overall, the percentage of male (68.7%) and female (68.1%) athletes injured was not different. No overall sex differences (variables collapsed) were observed in injury chronicity, location, type, events lost, mean number of injuries, or time to injury. Within sport differences existed for mean number of injuries, injury location, type of injury, and events missed. Mean time to injury in female basketball (28 days) and volleyball athletes (14 days) was significantly shorter compared to male basketball (67 days) and volleyball (65 days). Time to a concussion was significantly shorter in females overall compared to males. These results indicate that Canadian female university age athletes are not inherently more susceptible to injury, but female athletes within certain sports may have increased injury risk which could shorten time to injury (basketball, volleyball) and increase the number of events missed due to injury (hockey).

KEY WORDS: Sex differences, time to injury, sport, sprain, strain, concussion, muscle and tendon, shoulder, wrist and hand, groin and thigh

INTRODUCTION

The number of training and competition days lost due to injury is a significant issue in elite sport where a considerable burden is imposed upon the athlete with each injury occurrence (3). Varsity athletes defined as college and university level athletes are a key cohort in the North American sport development system. They make up a large proportion of all athletes in North America, with an estimated 498,165 athletes in the USA (38) and another 15,000 athletes in

Canada in 2021 (16). The North American intercollegiate athletic systems, (U-SPORT in Canada; National Collegiate Athletics Association (NCAA) in the USA) have been shown to be key years of athletic preparation for international and professional sport careers (15). However, being a varsity athlete carries with it a significant likelihood of injury, with 76% of varsity athletes having reported at least one injury in a season (26). Experts have cited this high incidence of injury as wholly unacceptable, especially when you consider the personal burden of sustaining an injury has on athlete's psychological and emotional welfare (28). In fact, it has been shown that injuries in Canadian university varsity sport athletes can lead to significant emotional disturbances not found in their uninjured teammates (22).

Of the available literature which has compared injury between sexes, the measures have been primarily incidence-based (13) or have solely focussed on a specific injury type, such as concussion (34) or location, such as the knee (19). Although incidence data can assist in depicting the injury profile in sport, other metrics can be used to better contextualize the influence of injury in a competitive season. Seminal work by Hootman and colleagues (20) has illustrated how injury rates differ by sport overall and by body part in college level varsity athletes but does not provide any understanding of how long an athlete might remain uninjured in a season. Of the available literature examining how long before an injury might occur, Swedish competitive male and female youth athletes (16-18 years of age) were asked retrospectively when they might have become first injured. The average time to first injury in this cohort was approximately 20 weeks (38%) into a 52-week training year (47). Potential sex-based differences in time to injury may also be evident in court based sports (volleyball and basketball) where self reported time to injury was shorter for females than sport matched males at the university sport level (26). Others have identified that the incidence of injury in female college volleyball athletes is greatest when a transition from low volume to high volume occurs, such as the summer to pre-season time period (53). Although these authors did not specifically look at time to injury, this study illustrates that more court based female athletes are injured early in the season (53). Collectively, the results of these projects highlight that if the time to injury is short and an injury occurs early in the season, the net effect of an athletes development can influence the overall performance in team based sports (2). The ripple effect of an injury can also be observed, where the psychological effects of returning to play have been shown to reduce the improvements that can be garnered over the course of a season (51). Furthermore, injury has also been cited as a key reason for drop out in youth sport (31), influences lifelong physical activity patterns after a collegiate sport career (14) and has a substantial long-term impact on an individual's health (6,32).

Of the existing literature which has examined overall injury rates between sexes, it remains unclear whether female athletes are more injured than males. At the high school level female athletes' injury rates are greater than males (47) with particularly large differences in chronic injury prevalence (49). At the college level, overall injury rates are similar in male and female American athletes, with specific sports (track, cross country running, basketball and soccer) reporting greater injury rates in female compared to male athletes (25). Canadian university injury research is limited and only one project has found that males had greater injury rates overall and females had a greater rate of severe injuries (21). Interestingly, research which has examined differences in body part injured and/or type of injury between sexes has found equivocal results. Female athletes report greater incidence of anterior cruciate ligament sprains (36), ankle sprains (10), and stress fractures (7) when compared to male athletes. Retrospective research in adolescent athletes has also found that females have greater lower body injury prevalence and less upper body injury occurrence compared to males (54). In contrast males have greater upper body (39) and groin (40) injury occurrence. Despite the equivocal injury rates of female and male athletes, there is still a perception that female athletes are more vulnerable (43) and self-report greater concern of injury than their male counterparts (51). This perception may be justified under certain circumstances where anterior cruciate ligament (ACL) injury research has identified that female athletes likely have greater risk (52) due to differences in joint structure. Additionally, females have less skeletal mass, muscle mass and lower absolute strength compared to males (46).

Adding more prospective injury research across a wide variety of sports at the college/university level can provide additional evidence to elucidate the differences in injury patterns between male and female athletes. Furthermore, our understanding of how time to injury differs between males and females is extremely limited and Canadian specific injury data across the main inter-university sports is insufficient. Thus, our aims were to examine how sex influences injury type and body part injured, injury occurrence, time to first injury and days lost due to injury in Canadian university athletes. Given that we were able to control for exposure by using male and female teams within the same/like sport, it was hypothesized that time to first injury would be similar in female athletes compared to male athletes. It was also hypothesized that a greater number of lower body injuries would occur in female athletes but that the type of injury would not differ between male and female athletes. Finally, it was hypothesized that events lost to injury would be greater in females compared to males.

METHODS

Participants

This study included 182 male and 113 female varsity athletes (n=295) attending a single Canadian University. The specific sports included ice hockey, basketball, soccer, wrestling, and volleyball, as well as football (male only) and rugby (female only). We used football and rugby as a matched cohort based on previous research which has used a similar process to compare injury occurrence in varsity athletes (21). Athletes were followed over the course of each sport's competitive varsity season. A minimum sample of 75 to 109 participants is sufficient to find a 15 % difference between sexes as statistically significant (deemed clinically important). This determination can be done by using a one-sided z-test to compare independent proportions with a power of 80% and an alpha level of 0.05 depending on the prevalence in the first group. We assumed proportion of athletes injured in males would vary between 48% (48) and 76% (26). Testing unidirectional hypotheses (one-sided test) was adopted because we postulated that, if a difference existed, that females would report more injuries than males based on Hurtubise et al. (21). To be eligible for participation in this study, athletes were required to have undergone a pre-participation evaluation which allowed them to be cleared for practice and competition. This study was approved by the local research ethics board (Study ID: Pro00009311) and each athlete completed an informed consent prior to their enrollment. There were no exclusion criteria, and given that the study aim was to monitor athletic injuries, no participants dropped out due to injury. Further, no participants discontinued study participation due to withdrawing from their university program or due to being let go from their team due to academic misconduct or other academic behaviour matters. This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (37). A description of the athlete cohort is provided in Table 1.

Table 1. Descriptive statistics for the sample of university varsity athletes monitored.

Sex	Sport	n	Age [years] mean (SD)	Height [cm] mean (SD)	Weight [kg] mean (SD)	BMI [kg/m²] mean (SD)	YOE [years] mean (SD)	YOE [years] median
Male	Hockey	29	22.9 (1.6)	182.5 (4)	85.5 (6)	25.6 (1.3)	2.8 (1.5)	3
	Basketball	15	20 (1.9)	194.1 (8.8)	91 (10.4)	24.1 (1.7)	2.5 (1.5)	3
	Soccer	20	19.5 (1.4)	179.8 (6.1)	77.3 (9.6)	23.9 (2.4)	2.3 (1.2)	2
	Wrestling	15	20.8 (3.1)	172.5 (5.6)	77.8 (17)	26 (4.8)	2.2 (1.1)	2
	Volleyball	19	20.4 (1.5)	193.2 (7.7)	87 (7.9)	23.3 (1.6)	3.4 (1.4)	4
	Football	84	21.1 (2.4)	184.1 (5.6)	98.8 (20.5)	29.1 (5.4)	2.2 (1.2)	2
		182	**21.0 (2.3)**	**184.2 (8.2)**	**90.5 (17.6)**	**26.6 (4.6)**	**2.4 (1.3)**	**2**
Female	Hockey	21	19.9 (1.5)	167.5 (4.7)	69.1 (6.8)	24.6 (2.1)	2.8 (1.3)	3
	Basketball	16	20.1 (2.9)	176.3 (3.9)	75.4 (11.1)	24.2 (3)	2.0 (1.2)	1.5
	Soccer	22	19.5 (1.8)	165.8 (5.4)	64.8 (9)	23.5 (2.6)	2.4 (1.4)	2
	Wrestling	8	18.4 (0.7)	160.5 (4)	60.4 (7.1)	23.4 (2.2)	1.4 (0.7)	1
	Volleyball	14	19.9 (1.4)	178.5 (5)	69.1 (8.5)	21.7 (2.1)	2.8 (1.2)	3
	Rugby	32	21.2 (2.4)	168.6 (6.4)	73.8 (12)	25.9 (3.7)	2.5 (1.4)	2
		113	**20.1 (2.2)**	**169.6 (7.3)**	**69.9 (10.6)**	**24.3 (3.1)**	**2.4 (1.3)**	**2**
Total		**295**	**20.7 (2.3)**	**178.5 (10.6)**	**82.5 (18.3)**	**25.7 (4.3)**	**2.4 (1.3)**	**2**

BMI = Body Mass Index, YOE = Year of Eligibility.

Protocol

Student kinesiologists working with each varsity team were responsible for prospectively recording each injury an athlete sustained throughout the entire competitive season including into playoffs. Each time an athlete reported an injury, the student kinesiologist would record all details pertaining to the injury at the practice or game. This hard copy datasheet was then inputted into a spreadsheet which included the date, injury location, injury type, injured structure, cause of the injury, acute or chronic injury, and whether the injury occurred in a game or a practice. The athlete was followed from the time of injury through the centralized athletic therapy care centre on campus until the athlete was cleared to return to practice and/or play. The decision for return to practice and/or play was determined by the full-time head athletic therapist in consultation with consulting sport medicine physicians when required. To determine the number of events (practices and competitions) they missed due to an injury, the number of officially scheduled practices and competitions that occurred while the athlete was sidelined was summed. The sum was a combination of the number of games and practices missed to account for the differing number and frequency of competitions across different sports. This value was then added to the injury data spreadsheet associated with that team. Once per week, research staff amalgamated the injury data from all teams into a single master datasheet.

Preliminary cleaning procedures were performed in Microsoft Excel which included categorization schemes reported in existing sports injury literature as detailed below. For location of injury, the categorization by Kay et al. (25) was utilized, with free-form responses from the raw data being synthesized prior to formal analysis. Similarly, the type of injury experienced was categorized, as presented in Table 3, based on an inductive analysis of the reported injury types by our team clinicians. The time to injury was also calculated based off the regular season start and the regular season end date expressed in both days as well as a percentage of the regular competitive season ((Injury date – Season start date)/(Season end – season start) * 100). Athletes continued to be tracked if their team proceeded into post competitive season play or competitions. This allowed for the determination of time to injury to be more accurately determined.

Statistical Analysis
Statistical analysis was performed in IBM SPSS® Statistics v.26 (IBM, Armonk, New York, NY, USA). Chi-Squares and Fisher exact tests (if cells included less than 5 observations) were performed to determine the significant differences in prevalence between sexes separately for body part injured, injury type, proportion of players injured, and acute injury and chronic injury, stratified by sport. Independent t-tests were used to detect significant sex differences in continuous measurements (mean time to first injury, mean number of injuries, mean number of events missed), with secondary analysis being conducted at the level of each sport. An alpha value of 0.05 was used to determine significance.

RESULTS

Injury Prevalence: Ninety-three athletes (57 males, 36 females) reported no injury and 202 (125 males, 77 females) reported at least one injury. The absolute total number of reported injuries was 404 where 98, 29, 26, 16, 12 and 1 athlete(s) had 1, 2, 3, 4, 5 and 6 reported injuries respectively. The total proportion of males reporting one or more injuries (68.7%) was not significantly different from females (68.1%) (Figure 1). The proportion of male soccer players who reported an injury was significantly larger than for female soccer players. Significant sex differences were not observed in any of the other sports (Figure 1). A greater proportion of female wrestlers reported at least one acute injury when compared to male wrestlers (100.0 %, 40.0 % respectively; $p<0.05$), with no differences in the proportion of chronic injuries reported between sexes on a sport by sport or overall basis (Figure 1). A greater proportion of athletes sustained an acute injury compared to chronic injury within each sex overall (Figure 1). Overall, the mean number of injuries were not different between male and female athletes (1.4 injuries per female and 1.4 injuries per male athlete, Figure 2). In contrast, there were significant differences within sports (Figure 2): the mean number of injuries per athlete was significantly greater in male hockey players compared to females (male=2.1, female=1.5), female basketball players compared to males (female=2.4, male=1.5) and male soccer players compared to female soccer players (male=1.6, female=0.6).

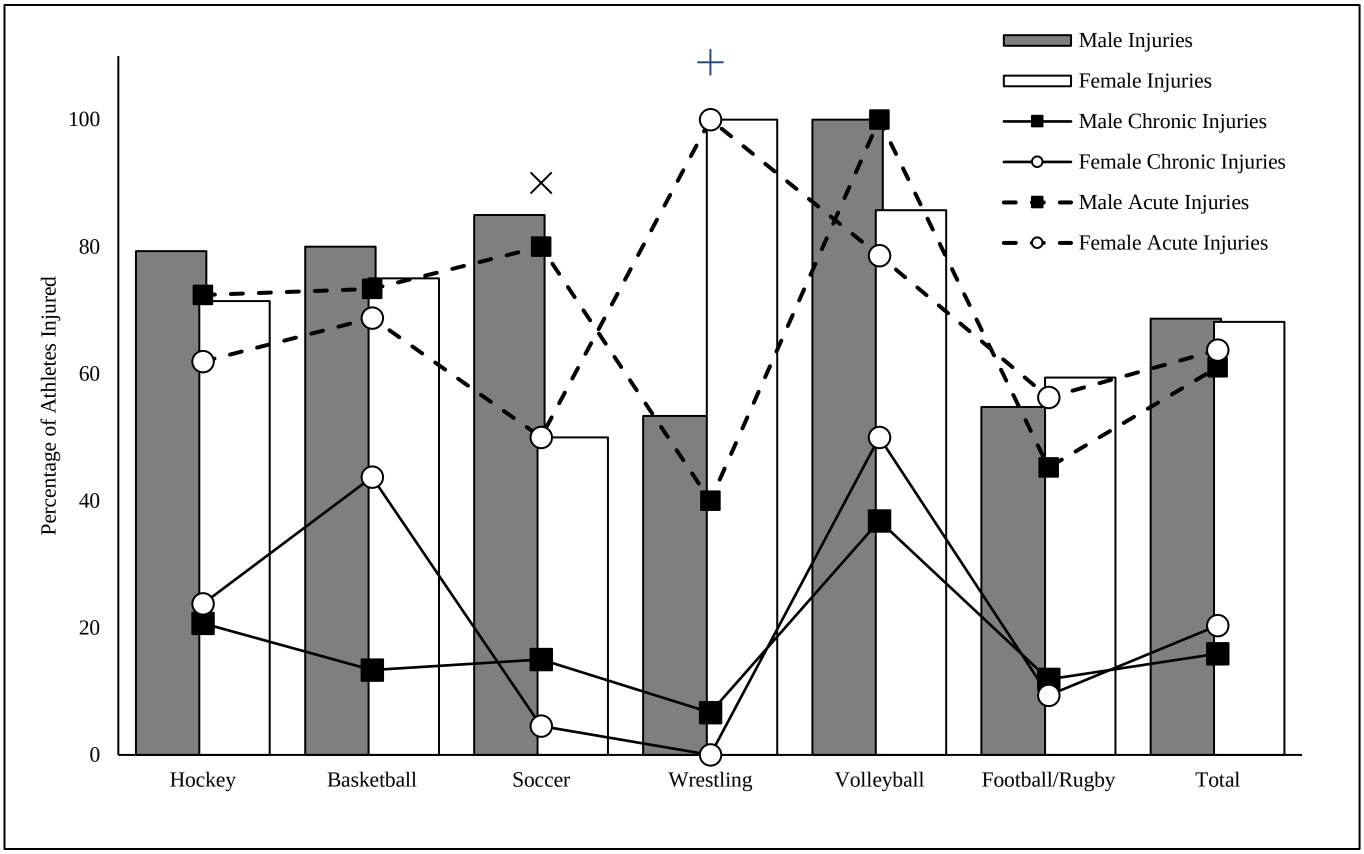

Figure 1. Percentage of male (grey) and female (white) varsity athletes injured over a single competitive season overall and within each sport. Percentage of athletes experiencing an acute (dashed line) and chronic (solid line) injury also reported for both male (■) and female (○) athletes. X Significant differences between overall male and female injury prevalence. + Significant differences between acute male and female injury prevalence.

Nature of Injuries: No significant differences were found in the prevalence of any single injury location between male and female athletes overall when grouping all the sports. The most common injury locations were the hip, groin, or thigh and lower leg, ankle or foot for both male and female athletes (Table 2). A significantly higher proportion of female wrestlers experienced a shoulder injury (62.5%) compared to male wrestlers (0.0%). A significantly higher proportion of female basketball players experienced an injury to the hip, thigh, or groin (50.0%) when compared to male players (6.7%). Male soccer players (40.0%) reported a higher proportion of hip, thigh, or groin injuries when compared to female soccer players (4.5%). There were no other significant sex differences in location of injury within the sports (Table 2). A visual representation of how injury incidence differs by injury for each sex is also depicted in Figure 3.

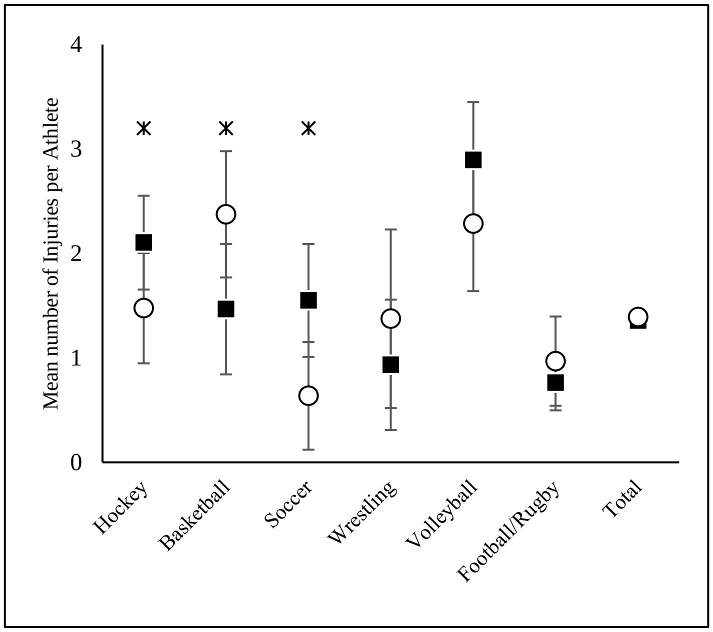

Figure 2. Mean number of injuries reported by male (■) and female (○) athletes over a single season overall and by sports. Error bars represent a 95% confidence interval. * Significant (P<0.05) differences between male and female athletes.

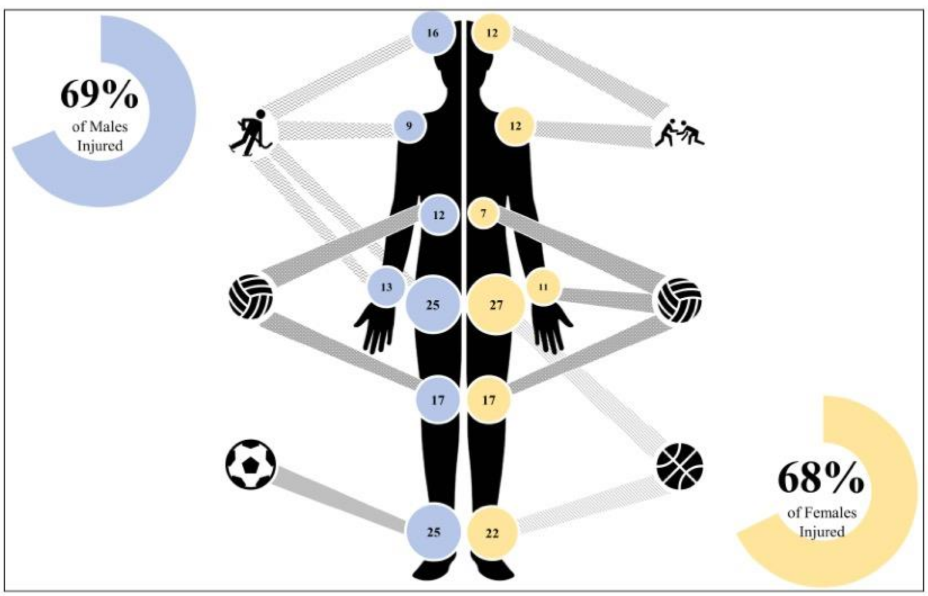

Figure 3. Sex differences in injury prevalence at different injury locations on the body. Blue (male) and yellow (female) circles describe the percentage of all athletes reporting an injury to that site over the duration of the competitive season. Male ice hockey players experienced the highest proportion of injuries to the head, neck, or face, shoulder, hip, thigh or groin, and hand or wrist. Male volleyball players had highest proportion of trunk and knee. Female volleyball players had highest proportion of trunk, knee and hand or wrist injuries. Female wrestlers experienced the highest proportion of injuries to the head, neck, or face and shoulder. Female basketball players experienced the highest proportion of injuries to the hip, thigh, or groin and lower leg, ankle, or foot. Male soccer players experienced the highest proportion of injuries to the lower leg, ankle, or foot. *Note: Sites with injury prevalence of <5% have been omitted from this graphic.*

No significant differences were found in the overall prevalence of any single injury type between male and female athletes when grouping all sports (Table 3). However, within sport, a significantly higher proportion of male soccer players (50.0%) sustained a muscle/tendon injury when compared to female soccer players (18.2%). No other significant within sport differences were found for injury type (Table 3).

Table 2. Number (% n) of athletes reporting one or more injuries to a specific location overall and depending on sex and sports.

Sex	Sport	n	Head, Neck, or Face	Shoulder	Elbow	Wrist or Hand	Trunk	Hip, Thigh, or Groin	Knee	Lower Leg, Ankle, or Foot	Upper Arm or Lower Arm
Male	Hockey	29	8 (27.6)	5 (17.2)	0 (0.0)	9 (31)	5 (17.2)	16 (55.2)	4 (13.8)	5 (17.2)	0 (0.0)
	Basketball	15	3 (20.0)	1 (6.7)	0 (0.0)	2 (13.3)	3 (20.0)	1 (6.7)	3 (20.0)	6 (40.0)	1 (6.7)
	Soccer	20	3 (15.0)	1 (5.0)	0 (0.0)	1 (5.0)	0 (0.0)	8 (40.0)	4 (20.0)	10 (50.0)	0 (0.0)
	Wrestling	15	4 (26.7)	0 (0.0)	2 (13.3)	2 (13.3)	1 (6.7)	2 (13.3)	1 (6.7)	2 (13.3)	0 (0.0)
	Volleyball	19	5 (26.3)	2 (10.5)	2 (10.5)	5 (26.3)	5 (26.3)	7 (36.8)	9 (47.4)	8 (42.1)	3 (15.8)
	Football	84	6 (7.1)	7 (8.3)	0 (0.0)	4 (4.8)	7 (8.3)	12 (14.3)	10 (11.9)	15 (17.9)	0 (0.0)
		182	**29 (15.9)**	**16 (8.8)**	**4 (2.2)**	**23 (12.6)**	**21 (11.5)**	**46 (25.3)**	**31 (17.0)**	**46 (25.3)**	**4 (2.2)**
Female	Hockey	21	5 (23.8)	0 (0.0)	0 (0.0)	4 (19.0)	2 (9.5)	7 (33.3)	4 (19.0)	2 (9.5)	1 (4.8)
	Basketball	16	0 (0.0)	1 (6.3)	0 (0.0)	2 (12.5)	0 (0.0)	8 (50.0) *	1 (6.3)	8 (50.0)	0 (0.0)
	Soccer	22	2 (9.1)	0 (0.0)	0 (0.0)	0 (0.0)	1 (4.5)	1 (4.5) *	2 (9.1)	6 (27.3)	0 (0.0)
	Wrestling	8	2 (25.0)	5 (62.5) *	0 (0.0)	0 (0.0)	1 (12.5)	2 (25.0)	1 (12.5)	0 (0.0)	0 (0.0)
	Volleyball	14	2 (14.3)	4 (28.6)	2 (14.3)	4 (28.6)	3 (21.4)	6 (42.9)	7 (50.0)	3 (21.4)	0 (0.0)
	Rugby	32	3 (9.4)	4 (12.5)	0 (0.0)	2 (6.3)	1 (3.1)	7 (21.9)	4 (12.5)	6 (18.8)	0 (0.0)
		113	**14 (12.4)**	**14 (12.4)**	**2 (1.8)**	**12 (10.6)**	**8 (7.1)**	**31 (27.4)**	**19 (16.8)**	**25 (22.1)**	**1 (0.9)**
Total		**295**	**43 (14.6)**	**30 (10.2)**	**6 (2.0)**	**35 (11.9)**	**29 (9.8)**	**77 (26.1)**	**50 (16.9)**	**71 (24.1)**	**5 (1.7)**

** Significantly different from corresponding male sport (p<0.05)*

Events Lost to Injury and Time to First Injury: Overall, male and female athletes did not differ significantly in the mean number of events a player missed due to injury (male=4.8, female=5.4) (Figure 4). When compared on a sport-by-sport basis, female athletes missed more events compared to the respective male team in hockey (female=11.1, male=2.1, $p<0.05$), basketball (female=6.4, male=3.1, $p>0.05$) and volleyball (female=9.3, male=4.3, $p>0.05$).

Table 3. Number (% n) of athletes reporting a specific type of injury overall, by sex and sports.

Sex	Sport	n	Dislocation, Subluxation, or Sprain	Bursitis	Cartilage	Concussion or Head Trauma	Fracture	Muscle or Tendon	Contusion	Nerve
Male	Hockey	29	6 (20.7)	1 (3.4)	1 (3.4)	6 (20.7)	3 (10.3)	16 (55.2)	11 (37.9)	0 (0.0)
	Basketball	15	8 (53.3)	0 (0.0)	2 (13.3)	1 (6.7)	0 (0.0)	5 (33.3)	1 (6.7)	0 (0.0)
	Soccer	20	5 (25.0)	1 (5.0)	1 (5.0)	1 (5.0)	0 (0.0)	10 (50.0)	2 (10.0)	1 (5.0)
	Wrestling	15	4 (26.7)	0 (0.0)	0 (0.0)	3 (20.0)	0 (0.0)	3 (20.0)	0 (0.0)	0 (0.0)
	Volleyball	19	11 (57.9)	2 (10.5)	3 (15.8)	3 (15.8)	1 (5.3)	13 (68.4)	1 (5.3)	0 (0.0)
	Football	84	15 (17.9)	2 (2.4)	2 (2.4)	5 (6.0)	5 (6.0)	13 (15.5)	9 (10.7)	0 (0.0)
		182	**49 (26.9)**	**6 (3.3)**	**9 (4.9)**	**19 (10.4)**	**9 (4.9)**	**60 (33.0)**	**24 (13.2)**	**1 (0.5)**
Female	Hockey	21	4 (19.1)	0 (0.0)	1 (4.8)	3 (14.3)	2 (9.5)	9 (42.9)	3 (14.3)	0 (0.0)
	Basketball	16	6 (37.5)	1 (6.3)	1 (6.3)	0 (0.0)	2 (12.5)	8 (50.0)	0 (0.0)	0 (0.0)
	Soccer	22	5 (22.7)	0 (0.0)	1 (4.5)	1 (4.5)	0 (0.0)	4 (18.2) *	1 (4.5)	0 (0.0)
	Wrestling	8	4 (50.0)	0 (0.0)	1 (12.5)	1 (12.5)	1 (12.5)	3 (37.5)	0 (0.0)	0 (0.0)
	Volleyball	14	7 (50.0)	0 (0.0)	1 (7.1)	1 (7.1)	0 (0.0)	10 (71.4)	1 (7.1)	0 (0.0)
	Rugby	32	8 (25.0)	0 (0.0)	2 (6.3)	1 (3.1)	0 (0.0)	9 (28.1)	5 (15.6)	0 (0.0)
		113	**34 (30.1)**	**1 (0.9)**	**7 (6.2)**	**7 (6.2)**	**5 (4.4)**	**43 (38.1)**	**10 (8.8)**	**0 (0.0)**
Total		**295**	**83 (28.1)**	**7 (2.4)**	**16 (5.4)**	**26 (8.8)**	**14 (4.7)**	**103 (34.9)**	**34 (11.5)**	**1 (0.3)**

** Significantly different from male corresponding sport ($p<0.05$)*

Mean time to injury as percentage of the competitive season was not different between male (32.3%) and female (28.9 %) athletes (Figure 5). Significant sport specific differences were observed between males and females competing in basketball (male=42.6 % or 67 days, female=17.9 % or 28 days), and volleyball (male=41.2% or 65 days, female=8.8% or 14 days). For football/rugby, the actual mean number of days to first injury was not different (male=15 days, female=16 days) however, percentage of season was different (male=21.5%, female=35.8%) due to the length of the rugby season being very short (Figure 5). Among different types of injuries, only the time to different concussion or head trauma differed between males and females (collapsed across sport) where females had significantly shorter time to concussion compared to males (Figure 6).

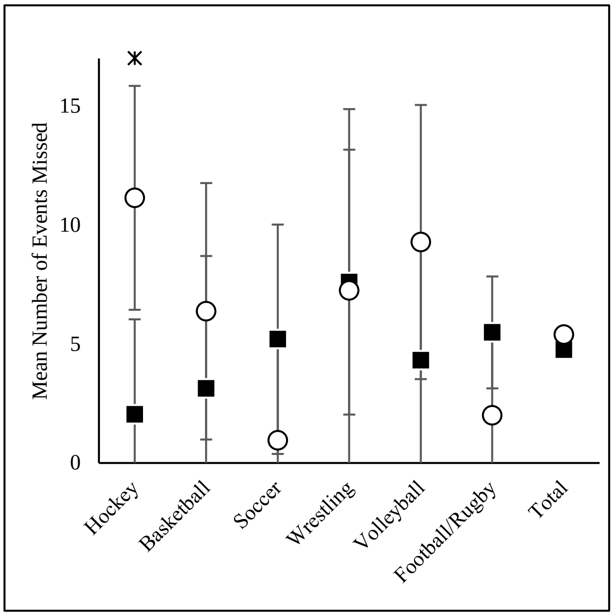

Figure 4. Average number of events (practice or game) missed by male (■) and female (○) athletes over a single competitive season due to injury overall and by sports. Error bars represent a 95% confidence interval. * Significant (P<0.05) differences between male and female athletes.

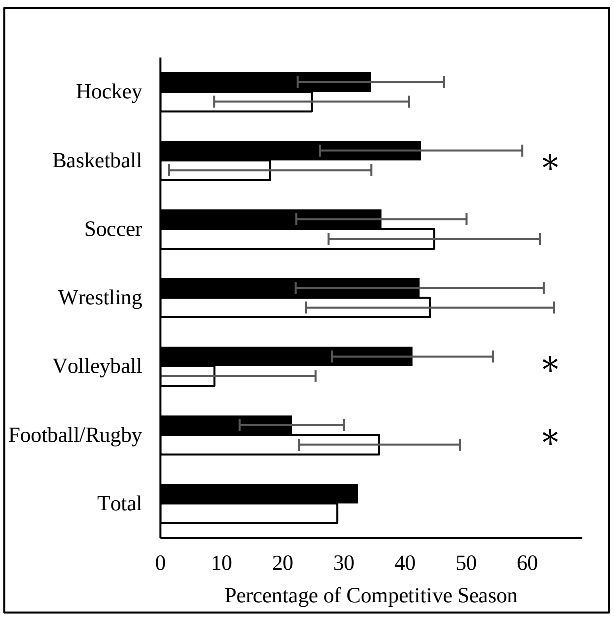

Figure 5. Mean time to first injury for male (■) and female (□) athletes, reported as a percentage of regular competitive season overall and by sports. Error bars represent a 95% confidence interval.* Significant (P<0.05) differences between male and female athletes.

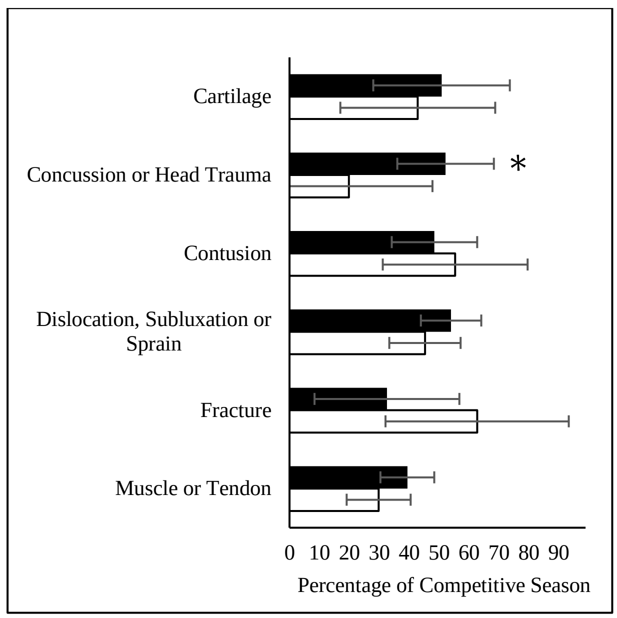

Figure 6. Mean time to first injury for male (■) and female (□) athletes, reported as a percentage of regular competitive season for different injury types. Nerve and bursa injuries excluded due to insufficient data. Error bars represent a 95% confidence interval. * Significant (P<0.05) differences between male and female athletes.

DISCUSSION

The results of this study show that male and female Canadian university varsity athletes have no overall significant differences in injury prevalence, injury type, injury location, or time to injury. However, when comparisons of these measures were made between male and female athletes competing in the same sport, significant differences were observed. This main finding reveals that females are not inherently more susceptible to injury (27), but rather sport specific factors may affect risk of injury in male and female athletes differently. The implications of these findings are described below.

Injury Prevalence: Despite no overall injury prevalence differences between males and females, it is notable that over 65% of male and female athletes reported an injury in their competitive season. The vast majority of these injuries were an acute injury (Figure 1). The overall prevalence observed in this study (Female 68% and Male 69%) is greater than that observed in NCAA athletes (Female 52% and Male 48%) (48) but less than the incidence reported in intramural sport students (Female 76% and Male 74%) (8) albeit the intramural data is from Turkish universities, not North American universities. When comparing injury prevalence across sexes within the same sport, we found that a higher proportion of male soccer players sustained an injury than female soccer players. Additionally, a higher proportion of female wrestlers reported an acute injury than male wrestlers (Figure 1). These results would align with NCAA data which found only two sports where female athlete injury incidence was greater (female swimming and female water polo) than males, with the authors concluding that there was considerably more "gender similarity than difference" (48). Further to this, Yang and colleagues found no difference in chronic or acute injury rates in 10 sex comparable NCAA sports (56). Others have found that injury rates are greater in female Canadian high school soccer, basketball (12) and varsity volleyball players but less in varsity basketball and hockey players compared to their male athlete counterparts (13). Thus, collectively our results in combination with other research, would indicate that across a broad spectrum of sports, there are no consistent trends in which sports might have greater rates of overall, acute, or chronic injury between male and female athletes, particularly at the university varsity level. However, it is still worthwhile considering why wrestling and soccer injury prevalence differed between sexes in our study.

This high prevalence of acute injury in female wrestlers may be partially attributed to the significantly greater prevalence of shoulder injuries (Table 2), all of which were acute. In contrast, elite Korean female wrestlers had 40% less reported upper extremity injuries in both acute and chronic injury categories when compared to male wrestlers (42). Why acute shoulder injuries are greater in amateur female wrestlers, including our study, is unknown. It is known ligament laxity can increase sprain risk, especially in extreme loading conditions of the shoulder joint (18). However, male high school wrestler who were positive for ligamentous laxity in the shoulder joint had 50 % less injuries than wrestlers that had no ligamentous laxity (44). Thus, the influence of overall shoulder joint stability on sport-specific injury risk remains equivocal and may be sex dependent. Given that the elite female wrestlers with superior strength also had less injuries (41), future research should continue to explore the benefits of improved shoulder fitness in female wrestlers at the university level on mitigating injury risk.

The mean number of injuries between sexes also differed in hockey, basketball, and soccer (Figure 2). These findings align with our acute and chronic prevalence rates for basketball and soccer, where male soccer players had greater overall and acute injury prevalence and female basketball players had a greater proportion of chronic injuries (Figure 1). In basketball, it has been well described that non-contact knee and ankle injuries are very common due to the frequent cutting, stopping, and jumping on hard court surfaces (23). Combined with the fact that females have altered afferent inputs in the leg, which can influence ankle joint position sensing, a known risk factor for ankle injury (55), it is possible this is the reason we have greater injuries per player in female basketball players compared to male players. Given that there was a total of 19 lower leg, ankle, or foot injuries in female basketball (compared to 7 in male basketball) with 50% of female basketball players each reporting at least one lower leg/ankle injury (Table 2), neuromuscular factors may contribute to injury risk in female basketball players. Furthermore, 8 out of the 19 total lower leg injuries were deemed chronic, which highlights the preventable nature of this high injury rate in female basketball players. Thus, these results suggest that injury risk may vary by sport depending on your sex. Further research should continue to explore how sport might affect injury risk in each sex.

Nature of Injuries: No significant differences were found between male and female athletes for injury type or location of injury when collapsed across sport. Yet, high incidence rates in specific body parts in some sports require further discussion. Within the male hockey, volleyball, and soccer teams, roughly half of the team had either a hip, thigh, or groin; knee; or lower leg/ankle injury respectively. This underscores that specific sports have specific risk factors for injury location, and that in some instances this incidence is influenced by sex as well. Others have also found that the lower leg/ankle is indeed a prevalent injury location in male soccer players (48) and groin injuries are a serious problem in male ice hockey players with higher incidence than in female ice hockey players (40). Thus, in soccer and ice hockey, our results suggest that male athletes may be at a greater risk, yet the reasons for this greater incidence remain unclear. However, it is possible that the female and male teams in the same sport might have different sets of risk factors associated with injury. This is illustrated in some of the sex-based differences in knee injuries as shown below.

Previous research has described greater risk of sustaining a knee injury in female athletes compared to male athletes (11), although knee injury incidence in female athletes compared to males in the same sport is less clear (48). Given that both male and female volleyball players in our study had the highest incidence of knee injury compared to other sports in their sex, and both reported some chronic and acute knee injuries (males 6 acute, 4 chronic; females 1 acute, 5 chronic), it is possible that sport specific factors lead to increased knee injury risk in volleyball. This is supported by research which found that jumping and landing in volleyball leads to high knee injury rates and this is not necessarily sex dependent (29). Given, the serious and debilitating nature of anterior cruciate ligament (ACL) injuries, especially in females (43), it is also worthwhile highlighting how sex or sport influenced our reported ACL injuries. In our study, 1 in 59 athletes sustained an ACL injury which is lower than the prevalence found in a recent systematic review (1 in 29 females and 1 in 50 male athletes) (35). Four of the ACL injuries occurred in females (hockey=2, volleyball=1, rugby=1) and one occurred in a male (football=1). The sports where ACL injuries were reported in our study is in keeping with male ACL prevalence data (20) but not female ACL prevalence data. Specifically, female ACL injury is 2-8 times more likely compared to males (30), but at the university level of sport, our female:male ACL incidence ratio was similar to other collegiate ACL injury data (1). Thus, although it is beyond the scope of this investigation to determine why more female athletes sustained an ACL injury, previous research would indicate it was likely a combination of sex specific and sport specific factors that led to this ACL incidence (30,54).

Given the increased awareness of the serious nature of head and neck injuries in sport, it is worth highlighting that the prevalence of both head, neck or face injuries and concussion/head trauma was not different between sexes overall (see Table 2 and 3). Our prevalence was significantly less than similar Canadian varsity sport data on concussion prevalence in males and females (21). The authors of that study indicated increased risk for females in sex-comparable sports compared to male athletes. Yet consensus on female specific risk of a concussion is inconclusive (33), which is illustrated by our results in 2 aspects. On a sport-by-sport basis we found males had greater concussion incidence than females (Table 3), but overall females time to a concussion was only 20% of the season compared to males at 52% of the season. We are the first to report time to first concussion in university varsity sport and have no greater insight into why female athletes had a significantly shorter time to concussion then male athletes.

What is more clear, is why concussion prevalence in the male sports of hockey and football is greater. Specifically, elevated male hockey incidence might be explained by the mechanism of injury where fewer females sustained a concussion through contact with another player, and more so due to contact with the ice (9). This highlights that sex specific sport rules may influence the prevalence of concussions, and this is predicated on the mechanism of injury (ice contact only in female versus hits and/or ice contact in male hockey). The influence of full contact however might be only part of the influence because when comparing two other full contact sports (rugby and football) the prevalence of concussions was higher in football compared to rugby. In this comparison, as reasoned by others, the use of a helmet may either weaponize the use of equipment to intentionally injure an opponent or prompt the athlete to act more aggressively (17), which results in higher concussion rates in football despite more protective equipment than rugby. Nevertheless, our results indicate that male athletes especially in the contact sports of hockey and football had more concussions and this may be due to a few key features of rules and equipment which are unique to the male game. Whether speed of impact or overall mass of male players influences the chance of a concussion especially in hitting/tackling situations should be a future avenue of research in distinguishing sex specific risk factors in concussion in contact sports.

Events Lost to Injury: In this study, the number of practice or game events missed per player was used as an index of time lost due to injury. Again, overall differences between the number of events missed due to injury between male and female athletes were not significant, but female hockey, volleyball and basketball athletes did miss more events than male players in the same sport. As time loss is often used as an indicator of injury severity (20), it is thought-provoking to see that 3 female teams did have greater time to recovery compared to male teams. It has been previously reported that Canadian female athletes report more severe injuries than males, the highest proportion being in female ice hockey players (21). The reasons why female athletes sustaining the same injury compared to males take a longer period to return to play is unclear. It is known that the culture surrounding how female injuries are treated by coaches differs when compared to male athletes (50), and that females have greater intrinsic fears related to their return to play (51). Thus, it is plausible that female athletes in hockey missed significantly more events because of either their perception that the specific injury was more severe, or the athletes' own fears might have delayed their return. Furthermore, male and female hockey players did not differ significantly on location nor type of injury, thus the aspects of culture and intrinsic fears related to injury are likely more important in how return to play is managed in hockey and should be an avenue for future exploration.

Time to First Injury: Female athletes had a shorter time to first injury compared to male athletes, albeit the difference was small and not statistically significant (male = 32.3% compared to females at 28.9% of season). The more insightful finding is that both males and females who are injured on average do so in the first 3rd of their competitive season. This early onset of injury in the competitive season can be partly explained by a few key sports (volleyball and basketball) where female athletes in these sports have a significantly shorter time to injury (9% and 18% respectively) although this is contrasted with female rugby which had a significantly longer time to injury at 36% compared to its matched sport – football at 22%. Previous retrospective research has also found that female university varsity basketball and volleyball athletes had a significantly shorter time to injury (26). In reference to rugby and football, we felt comfortable comparing these two sports due to similar competitive structures (24) and the fact that other Canadian research compared rugby to football, finding greater severe injury incidence in football compared to rugby (21). Interestingly, male professional rugby compared to football has a 3-fold injury risk (24) which suggests that both level of play and sex differences may impact injury risk. Yet, besides time to injury, there were no other discernable differences in rugby vs. football including number of injuries, proportion of players injured, and type of injury sustained in our study. Furthermore, despite the high-contact collision nature of rugby and football, the injury incidence and prevalence (overall, chronic) were lower than most other sports in our study. This may illustrate that full contact sports such as football and rugby are not inherently riskier than noncontact varsity sports and is in keeping with previous research which found similar injury incidence compared to other university age varsity team sports (21).

This research shows that sex alone does not predict athlete injury risk at the university sport level, but specific sports have risk factors that might influence a sex specific factor to heighten injury risk. Our findings add to the understudied area of research which explores "time to injury". Specifically, we found that females do not have a significantly shorter time to injury and that the combinative nature of sport and sex specific factors drastically reduces time to injury especially in female basketball and volleyball players. We believe that the calibre and fitness of the athletes from the university varsity program we studied is similar to most, large full complement university varsity programs in Canada and would be similar to many Division 2 and 3 NCAA varsity programs. Thus, these findings likely have real world implications in how court (basketball and volleyball specifically) sport athletes are coached and trained. Furthermore, this research highlights that in the court sports, a large reduction in uninterrupted time to train physical, tactical and technical training within a competitive season can be attributed to injury. Track and field research has shown that missing 20 % of training across a competitive season significantly reduces your likelihood of achieving your performance goal (45). The same inference might be made for team sports, where the ability for coaches to field the best team possible is altered in those sports where the onset of injury is early (female volleyball and basketball) and the incidence is high (female wrestling, male volleyball). Furthermore, our results lend credibility to the proposed multifactorial injury mechanism risk model where sex is cited as a key internal factor that in combination with external factors heightens risk of injury (i.e. female court sports of basketball and volleyball) (4). However, our results also show that the incidence of female wrestling injuries and time to return to play for female hockey players are wholly unacceptable, which further illustrates that a sport and sex combination likely heightens injury risk and delay's return to play in female athletes. Finally, once injured the loss of training likely has numerous negative outcomes on an individual level (5,28) and for a team's ability to perform optimally (2).

Limitations of this study included only one year of prospective data collection. As with any longitudinal data collection, having multiple time periods over years reduces any potential outliers, or other variables that might have been unique to that initial data collection period. We also relied on student therapists to collect the data on a daily basis. The student therapists were trained in how to record and report injuries, however there may have been some errors in how the injury was initially recorded. We also were reliant on the athlete self identifying an injury, unless it was obvious and the athlete required immediate assistance for an acute injury. Finally, this study only looked at the sports which had a student therapist(s) assigned to the team. There were additional sports which could have been studied including curling, tennis, swimming, track and field, and cross country running, however as stated we did not have the staff to ensure we could reliably collect data in those other teams not included.

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