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Sex Differences in Reported Concussion Injury Rates and Time Loss From Participation: An Update of the National Collegiate Athletic Association Injury Surveillance Program From 2004–2005 Through 2008–2009

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Context: Epidemiologic studies have identified differences in concussion incidence between the sexes. However, few authors to date have updated injury rates (IRs) and time loss between male and female concussed athletes.

Objective: To examine sex differences in IRs and time loss in concussed National Collegiate Athletic Association (NCAA) athletes.

Design: Descriptive epidemiologic study.

Setting: National Collegiate Athletic Association athletics.

Patients or Other Participants: A total of 1702 concusssed NCAA athletes, consisting of 903 females and 779 males participating in soccer, basketball, ice hockey, lacrosse, softball, or baseball over a 5-year period from 2004–2005 through 2008–2009.

Main Outcome Measure(s): Using the NCAA Injury Surveillance Program, athletic trainers reported concussions, athlete-exposures (AEs), and time loss across 10 NCAA sports. An IR is the number of injuries in a particular category divided by the number of AEs in that category.

Results: During the study period, 1702 concussions were reported during 4 170 427 AEs for an overall total of 5.47 per 10 000 AEs. In sex-comparable sports, females had a 1.4 times higher overall concussion IR than males (IRs = 4.84 and 3.46, respectively), with greater rates in women's baseball/softball, basketball, ice hockey, and soccer than men. Female soccer and basketball players also displayed more time loss after concussion compared with male basketball and soccer players.

Conclusions: Female athletes sustained a higher rate of concussion and, in all sports except lacrosse, had greater time loss from concussion than male athletes. Additional research is needed on sex differences in time loss after concussions.

Key Words: epidemiology, traumatic brain injuries, sports

Key Points

- Female collegiate athletes had a higher concussion rate in baseball/softball, basketball, ice hockey, and soccer than their male counterparts.
- In all sports except lacrosse, female collegiate concussed athletes took longer to recover from their concussions than did male collegiate concussed athletes.

An estimated 1.6 million to 3.8 million sports and recreational traumatic brain injuries occur each year in the United States.[1] Researchers[2–6] conducting epidemiologic studies using sport injury databases (eg, National Collegiate Athletic Association Injury Surveillance Program [NCAA ISP]) have identified differences in the concussion incidence between female and male high school and collegiate athletes. Female athletes at both the high school and collegiate levels have a greater incidence of reported concussion in sports played by both sexes, such as baseball/softball, basketball, ice hockey, and soccer.[3,4,6] However, investigators have only examined epidemiologic NCAA data available through 2004. Given the increased educational and awareness efforts and improved management policies implemented by the NCAA for sport-related concussion during the past 10 years, further examination of the rates of concussion among male and female athletes is warranted.

To date, few authors of epidemiologic studies have examined injury rates (IRs) at the collegiate level.[2,4] Hootman et al[4] summarized 16 years (1988–2004) of NCAA ISP data across 15 sports. Concussion IRs in women's sports were higher than in men's sports. Specifically, the concussion IRs per 10 000 athlete-exposures (AEs) for women's softball (IR = 1.4), basketball (IR = 2.2), ice hockey (IR = 9.1), and soccer (IR = 4.1) were all higher compared with men's baseball (IR = 0.7), basketball (IR = 1.6), ice hockey (IR = 4.1), and soccer (IR = 2.8). However, these studies included NCAA data only for 1988–2004. More recent data on collegiate athletes are needed to compare with previously published data to identify any changes for sport and sex.

Epidemiologic data gathered at the high school level suggest that sex differences in concussion IRs are also evident. In 2012, Marar et al[3] compared injury trends among male and female high school athletes based on data gathered during the 2008–2010 athletic seasons. A total of 1936 concussions were reported during 7 780 064 AEs. In sex-comparable sports, concussion IRs per 10 000 AEs were higher for female athletes (IR = 1.7) compared with male athletes (IR = 1.0). Specifically, girls' soccer (IR = 3.4), basketball (IR = 2.1), and softball (IR = 1.6) all had higher concussion rates than boys' soccer (IR = 1.9), basketball (IR = 1.6), and baseball (IR = 0.5). Similarly, Lincoln et al[6] examined IRs in a sample of 25 high schools over an 11-year period (1997–2008). Compared with boys, girls had a higher rate ratio (RR: an estimate of the relative risk based on IRs) per 10 000 AEs of concussion in soccer (RR = 2.1), softball (RR = 1.9), and basketball (RR = 1.7).[6] These data suggest that males and females at the high school level differ in the incidence of reported concussions, with female athletes having a higher incidence.

In addition to examining sex differences in the IRs of concussion, documentation of time loss from sport participation due to concussion is also relevant and understudied in collegiate athlete populations. Identifying time loss from concussions is important so that we can determine if females or males take longer to recover, which will inform clinical care in this at-risk population. In previous studies of high school athletes, female concussed athletes competing in basketball, lacrosse, and soccer, demonstrated greater time loss from participation than did male concussed athletes competing in similar sports.[6] Similarly, Zuckerman et al[7] reported that female concussed athletes (middle school, high school, college) had greater time loss before their total symptom score returned to baseline compared with male concussed athletes (9.1 versus 7.0 days, respectively). In contrast, Frommer et al[8] failed to document sex differences in time loss from participation between male and female high school concussed athletes. Although these results support sex differences in time loss from participation due to concussive injury at the youth and high school levels, whether these differences exist in the collegiate population is unknown.

Documenting epidemiologic trends for the incidence of and time loss from participation after sport-related concussion is important for sports medicine professionals treating these athletes. Clinicians should be aware of which athletes may be self-reporting a concussion and which athletes may have a protracted recovery. Moreover, identifying sex differences in incidence rates and time loss from participation after concussion could both complement and support differences between male and female athletes. We provide an updated examination of concussion IRs and time loss from participation among male and female NCAA concussed athletes from 2004–2005 through 2008–2009. We hypothesized the following: (1) The IRs for female concussed athletes would be higher than for male concussed athletes. (2) Female concussed athletes would exhibit greater time loss from participation compared with male concussed athletes.

METHODS

Operational Definition of Concussion

Concussion was operationally defined as "a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces."[9] A *reportable concussion* in the NCAA ISP was defined as one that (1) occurred as a result of participation in an organized intercollegiate practice or competition, (2) required medical attention by a team certified athletic trainer (AT) or physician, and (3) resulted in restriction of the student-athlete's participation or performance for 1 or more calendar days beyond the day of injury. If an off day followed the injury event, ATs were asked to assess whether the injured athlete would have been able to participate. The diagnosis of a reported concussion was left to the discretion of the ATs and physicians. These individuals used their respective schools' concussion-identification and concussion-management guidelines. Only sport-related concussions were included in this study.

Athlete-Exposure

We defined 1 *AE* as attending 1 session of either a game or practice. The total number of AEs for a particular sport team was calculated as the sum of the total number of games and practices attended by the athletes on that team. The ATs completed weekly forms and did not include athletes who were injured, ill, or missing in their AE calculation.

Time Loss

Recovery time from a reported sport-related concussion (ie, total days since injury) was determined by the date of medical clearance for return to full, nonrestricted participation in games. Return to participation was determined by the ATs and physicians once the athletes cleared the concussion protocols at their institutions. The date of return to full, nonrestricted participation for each reported concussed athlete was entered into the electronic form by the AT.

Injury Rate

An *IR* is a measure of the incidence of injury, defined as the number of injuries in a particular category divided by the number of AEs in that category. For concussion in the NCAA ISP, this value was expressed as concussion injuries per 10 000 AEs. Previous authors have reported IRs per 10 000 AEs,[10,11] which are easier to interpret than 1000 AEs (ie, 7.85/10 000 AEs versus 0.785/1000 AEs).

Procedures

The NCAA ISP is operated by the Datalys Center for Sports Injury Research and Prevention, Inc, which is an independent nonprofit research center. The NCAA ISP is a surveillance system that collects a variety of data elements for all NCAA sports across all 3 NCAA divisions. Exposure variables consist of the total number of males and females participating in their specified sport by practice or competition. Concussion data consist of the total number of reported concussions per sport, competition, and practice

Table 1. Practice and Game Athlete-Exposures by Male and Female Sports

National Collegiate Athletic Association Sport	Athlete-Exposures		
	Practice	Game	Total
Men's baseball	413 224	213 526	626 750
Women's softball	243 621	174 480	418 101
Men's basketball	520 998	131 830	652 828
Women's basketball	458 373	130 396	588 769
Men's ice hockey	208 010	61 483	269 493
Women's ice hockey	89 563	29 203	118 766
Men's lacrosse	195 210	34 382	229 592
Women's lacrosse	147 508	34 868	182 376
Men's soccer	413 160	114 034	527 194
Women's soccer	419 721	136 837	556 558

and time loss from concussion. All reported concussions and AEs were entered by ATs using a detailed electronic injury-report form that was completed on a Web-based system. The ATs completed the injury forms weekly and could view and update previously submitted forms as needed throughout the academic year. The detailed injury form was standardized for all ATs. The Datalys Web system includes a verification process that reviews entries and flags invalid entries. Datalys exported the data from the NCAA ISP across 10 sex-comparable NCAA sports, over a 5-year period from 2004–2005 through 2008–2009. Although some of the sports have different rules (ie, checking in ice hockey for males), they are comparable because they are the same sport (ie, male soccer, female soccer), played in the same environment (ie, ice arena), with the same AEs, and with the same season length. All data were considered exempt by the Michigan State University Institutional Review Board, as no identifying variables were present.

Data Analysis

The IRs for all male and female sports were calculated. To compare IRs between male and female reported concussed athletes and among the sports, we calculated rate ratios (RRs). The RR compares the IR for 1 group or condition (eg, females) with the IR of another group or condition (eg, males). It is calculated by dividing the IR of 1 group by the IR of the other group and provides an indication of where risk is concentrated. All IRs and RRs are presented using 95% confidence intervals. Also, *t* tests were conducted to determine sex differences for time loss from participation in comparable sports. Due to multiple comparisons, we performed a Bonferroni correction; therefore, significance was set a priori at $P = .01$. All data analyses were conducted using SPSS (version 21; IBM Corporation, Chicago, IL).

RESULTS

Concussion IR

Practice AEs totaled 1 358 786 for females and 1 750 602 for males during the 5-year study period (Table 1). In regard to game AEs, females had 505 784 and males had 555 255. A total of 799 (46.9%) reported concussions occurred in NCAA male players and 903 (53.1%) in NCAA female players (Table 2). Of all the reported concussions, 42 athletes (2.5%; males = 24, females = 18) sustained multiple concussions during the 5-year study period. Two-thirds of these multiple concussions occurred in competition (n = 28, 67%), with the rest occurring in practice (n = 14, 33%). Most of the reported concussions occurred in season (n = 1284, 75.4%), followed by preseason (n = 348, 20.4%) and postseason (n = 73, 4.3%).

A total of 1045 (61.4%) reported concussions occurred in competition and 657 (38.6%) reported concussions occurred in practice. The prevalence of reported concussions was also higher in competition than in practice for all 10 sports (Table 3). The highest competition IR was men's lacrosse (22.98). This was followed by men's ice hockey (20.66), women's soccer (18.9), women's ice hockey (17.81), and women's lacrosse (14.91). When examining competition compared with practice sessions, men's ice hockey had a 12.99 times greater rate, followed by men's lacrosse (9.74), men's soccer (7.69), women's soccer (7.84), and women's ice hockey (6.14).

When examining sex differences in the 5 comparable sports of softball/baseball, basketball, ice hockey, lacrosse, and soccer, females (IR = 4.84) had a 1.40 times higher overall IR than males (IR = 3.46). Specifically, females had a higher overall concussion IR than males, respectively, for ice hockey (6.57 versus 5.94), soccer (6.45 versus 4.19), basketball (4.67 versus 3.34), and softball (2.34 versus 1.20). The only sport in which males had a higher concussion IR than females was lacrosse (5.44 versus 4.99, respectively; Table 3). When examining the relative risk for a reported concussion, female softball players had almost a 2 times greater risk compared with male baseball players (RR = 1.95, 95% confidence interval [CI] = 1.45,

Table 2. Practice and Game Concussions by Preseason, In Season, and Postseason for Male and Female Athletes

National Collegiate Athletic Association Sport	Concussions						
	Practice			Game			
	Preseason	In Season	Postseason	Preseason	In Season	Postseason	Total
Men's baseball	11	9	0	0	52	3	75
Women's softball	14	20	0	1	61	2	98
Men's basketball	79	53	6	5	70	5	218
Women's basketball	69	76	4	3	119	4	275
Men's ice hockey	11	21	1	5	116	6	160
Women's ice hockey	5	20	1	0	51	1	78
Men's lacrosse	29	15	2	2	73	4	125
Women's lacrosse	25	12	2	0	51	1	91
Men's soccer	30	39	2	8	129	13	221
Women's soccer	45	55	1	6	239	13	359

Table 3. Practice and Game Concussion Injury Rates (IRs) by Male and Female Sports

National Collegiate Athletic Association Sport	IR (95% Confidence Interval)			Rate Ratio[a]	Total IR/10 000 AEs (Hootman et al[4])	Rate Ratio[b]
	Practice	Game	Total			
Men's baseball	0.48 (0.30, 0.75)	2.58 (1.94, 3.35)	1.20 (0.94, 1.50)	5.38	0.7	1.71
Women's softball	1.40 (0.97, 1.95)	3.67 (2.82, 4.68)	2.34 (1.90, 2.86)	2.62	1.4	1.67
Men's basketball	2.65 (2.23, 3.13)	6.07 (4.81, 7.55)	3.34 (2.91, 3.81)	2.29	1.6	2.08
Women's basketball	3.25 (2.75, 3.82)	9.66 (8.45, 11.50)	4.67 (4.14, 5.26)	2.97	2.2	2.12
Men's ice hockey	1.59 (1.09, 2.23)	20.66 (17.22, 24.57)	5.94 (5.05, 6.93)	12.99	4.1	1.45
Women's ice hockey	2.90 (1.90, 4.25)	17.81 (13.30, 23.34)	6.57 (5.19, 8.20)	6.14	9.1	0.72
Men's lacrosse	2.36 (1.73, 3.14)	22.98 (18.20, 28.63)	5.44 (4.53, 6.49)	9.74	2.6	2.09
Women's lacrosse	2.64 (1.88, 3.61)	14.91 (11.14, 19.55)	4.99 (4.02, 6.13)	5.64	2.5	2.0
Men's soccer	1.72 (1.34, 2.17)	13.15 (11.94, 16.38)	4.19 (3.66, 4.78)	7.64	2.8	1.50
Women's soccer	2.41 (1.96, 2.92)	18.90 (16.76, 21.45)	6.45 (5.83, 7.19)	7.84	4.1	1.58

Abbreviation: AEs, athlete-exposures.

[a] Rate ratio between game and practice IRs.

[b] Rate ratio between results of Hootman et al[4] and current IRs.

2.65), female soccer players had a 1.54 times greater risk compared with male soccer players (95% CI = 1.31, 1.83), female basketball players had a 1.4 times greater risk (95% CI = 1.17, 1.67) compared with male basketball players, and female ice hockey players had a 1.1 times greater risk (95% CI = 0.84, 1.30) compared with male ice hockey players. Male lacrosse players were at a 1.1 times greater risk (95% CI = 0.832, 1.43) than female lacrosse players for incurring a reported concussion in either practice or competition.

When we compared the findings of Hootman et al[4] with ours, all sports except women's ice hockey had increases in reported concussion IRs. Women's basketball (RR = 2.12), men's basketball (RR = 2.08), men's lacrosse (RR = 2.09), and women's lacrosse (RR = 2.0) all had a 2.0 or more times greater risk for reported concussions during the 2004–2005 through 2008–2009 compared with the previous 15 years. See Table 4 for complete RR information from Hootman et al[4] and us.

Time Loss From Participation in Sex-Comparable Sports

Female soccer players (mean = 9.33 ± 8.54 days) took longer to return to participation than male soccer players (6.14 ± 6.15 days) from reported concussions that occurred in practice ($t = -2.78$, $P = .006$). Time loss for reported concussions that occurred in competition did not differ between male (8.2 ± 8.07 days) and female (7.95 ± 6.21 days) soccer players ($t = 0.449$, $P = .67$). Female basketball athletes (7.40 ± 7.10 days) also took longer to recover from reported concussions that occurred in competitions than did male basketball athletes (5.57 ± 3.39 days, $t = -2.47$, $P = .01$). However, female basketball players (7.78 ± 8.10 days) and male basketball players (6.02 ± 6.50 days) did not differ in time loss after reported concussions that occurred during practice sessions ($t = -1.98$, $P = .048$). No other sex differences were noted for reported concussions that occurred in baseball/softball (practice: $t = -0.110$, $P = .912$; competition: $t = -0.226$, $P = .828$), ice hockey (practice: $t = -0.126$, $P = .90$; competition: $t = 1.33$, $P = .89$; Table 4), or lacrosse (practice: $t = 2.32$, $P = .022$; competition: $t = 1.46$, $P = .156$) players.

DISCUSSION

The current study provides an important update on epidemiologic trends for reported concussion IRs and time loss after a reported concussion for male and female NCAA athletes. Our primary findings demonstrate that females participating in sex-comparable sports (eg, basketball, soccer) had a 1.4 times greater incidence of reported concussion than males. Female softball players self-reported a 1.95 times greater incidence of a reported concussion than did baseball players. Female soccer and basketball players had nearly a 1.5 times greater incidence of a reported concussion than did male soccer and basketball players. When comparing our findings with those of the previous 15 years,[4] we found that collegiate athletes were at greater risk for incurring a reported

Table 4. Time Loss for Practice and Game Concussions by Male and Female Sports

National Collegiate Athletic Association Sport	Practice Concussions, No.	Days ± SD (*P* Value)	Competition Concussions, No.	Days ± SD (*P* Value)
Men's baseball	18	7.56 ± 5.74	53	8.04 ± 6.88
Women's softball	30	7.97 ± 6.64 (.828)	54	8.19 ± 6.96 (.912)
Men's basketball	130	6.02 ± 6.50	70	5.57 ± 3.39
Women's basketball	144	7.78 ± 8.10 (.048)	119	7.40 ± 7.10 (.01)[a]
Men's ice hockey	74	8.93 ± 7.34	32	8.75 ± 7.75
Women's ice hockey	25	6.67 ± 4.97 (.190)	48	9.96 ± 7.45 (.897)
Men's lacrosse	40	8.70 ± 7.99	74	8.93 ± 7.34
Women's lacrosse	34	6.65 ± 3.89 (.156)	50	6.16 ± 5.89 (.022)
Men's soccer	70	6.14 ± 6.15	147	8.27 ± 8.07
Women's soccer	94	9.33 ± 8.54 (.006)[a]	257	7.95 ± 6.21 (.67)

[a] Greater time loss for females compared with males.

concussion. In addition, female basketball and soccer athletes had greater time loss from a reported concussion compared with male basketball and soccer players.

The current results are consistent with those of previous researchers[3,4,6] who documented higher concussion rates for females than males in baseball/softball, basketball, ice hockey, and soccer. These findings have been attributed to greater peak head and neck angular acceleration in female athletes.[12] Females may also have a greater incidence of reported concussions due to increased blood flow,[13] neuroanatomical differences (ie, greater area of unmyelinated neuronal processes),[14] or potentially the female sex hormone estrogen.[15] Females have also been noted to have a higher incidence of migraine headaches than males, which may have contributed to the increased incidence of females reporting concussions.[16] Researchers[8,17] have also reported a discrepancy by sex in symptom reporting, as female athletes reported more concussion symptoms than did male athletes. The explanations for increased concussion-symptom reporting for females compared with males are unclear, but females may be more honest in reporting symptoms,[18] whereas males may underreport their symptoms.

Other than ice hockey, all sports had a greater incidence by at least 1.5 times for reported concussion in 2004–2005 through 2008–2009 compared with the previous 15 years. Moreover, women's and men's basketball and lacrosse had a 2.0 times greater incidence for a reported concussion in 2004–2005 through 2008–2009. This increase in reported concussions could be attributed to increased awareness by both the media and health care professions, along with increases in athletes reporting concussions. Although we did not study this factor, it may be that collegiate athletes were more aware of the dangers of playing with a concussion or more willing to report their concussions to a sports medicine professional. In regard to ice hockey, we do not know why the rate in women's ice hockey decreased.

The present study indicated partial support for differences in the concussion incidence in sex-comparable sports and time loss from participation. Specifically, females had greater time loss than males in basketball and soccer. These results were similar to those of Marar et al,[3] who also reported greater time loss for female concussed athletes compared with male concussed athletes but contrast with those of Frommer et al,[8] who reported no differences in time loss between female and male high school athletes. Concussions were included only if the injury was reported to the AT or physician, and therefore, concussion reporting may reflect sex differences, as females may tend to be more honest about reporting their symptoms. In addition, increased severity of reported concussions for female athletes participating in basketball and soccer may have accounted for greater time loss. Finally, the reported concussions had to result in a time loss of 1 or more days to be included in the study. As expected, due to the difference in the contact rules between men and women's lacrosse, female lacrosse athletes displayed fewer overall reported concussions in competition and practice. In ice hockey, however, females sustained a greater number of reported concussions in games than their male counterparts but fewer during practice. This could be attributed to the females' practices involving less collision and more fundamental skills. In a game situation, females may be less likely to mechanically take the forces due to decreased neck strength, girth, and mass.[12]

A consensus appears to be emerging that, in sex-comparable sports, female athletes at the collegiate level experience a greater number of reported concussions than males. Whether this information depicts a true sex difference in concussion incidence or is a result of sex differences in concussion-reporting behaviors (ie, females overreport, males underreport, or both), the sports medicine professional should be aware of the concussion occurrence in female athletes. These data warrant the continued study of recovery outcomes among male and female concussed athletes.

Our findings revealed that NCAA athletes self-reported a greater incidence of concussions in competition compared with practice sessions for all 10 sports. The sports with the highest competition IRs were men's ice hockey and lacrosse and women's ice hockey, lacrosse, and soccer. Our results are consistent with those of other researchers[3,5,19,20] who also reported higher IRs in competition than in practice sessions. Several reasons may explain why collegiate athletes incurred more reported concussions in competitions compared with practices. First, the level of intensity is greater in competition than practice, resulting in more injuries.[21] Second, physical contact between players is increased during competition compared with practice sessions.[22] Finally, more illegal contact may take place during competition compared with practice.

This study was not without limitations. An injury was included in the dataset only if the athlete self-reported it to the AT or physician or if the athlete was removed from participation by an AT or physician and had a time loss of 1 or more days. Any concussions that were not accurately diagnosed or that did not hold the athlete out for 1 or more calendar days were excluded from the study. The definition of concussion used by the NCAA ISP is vague, which may have resulted in variations in concussion diagnosis by sports medicine professionals. Another limitation was the AE definition as 1 player attending 1 session of either a game or practice. This definition does not take into consideration the total amount of exposure time in a practice or game. A final limitation to the study was the definition of return to play. Sports medicine professionals used their own judgment in determining when a concussed athlete was ready to return to participation. As a result, there may have been variations from site to site as to when a concussed athlete was returned to participation.

Future researchers should continue to examine the incidence rate and time loss from concussions, especially at the collegiate level. Nonreported concussions in both males and females should be examined to determine if the differences are due to reporting bias or to females truly sustaining more concussions. Investigators should also continue to study biomechanical differences between the sexes, along with advances in rule changes and protective equipment, which may predispose an athlete to or decrease an athlete's likelihood of sustaining a concussion and time loss from injury. Finally, future authors should identify the potential effects of NCAA rule and policy changes on concussions.

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