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Ball-Contact Injuries in 11 National Collegiate Athletic Association Sports: The Injury Surveillance Program, 2009–2010 Through 2014–2015

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Context: Surveillance data regarding injuries caused by ball contact in collegiate athletes have not been well examined and are mostly limited to discussions of concussions and catastrophic injuries.

Objective: To describe the epidemiology of ball-contact injuries in 11 National Collegiate Athletic Association (NCAA) sports during the 2009–2010 through 2014–2015 academic years.

Design: Descriptive epidemiology study.

Setting: Convenience sample of NCAA programs in 11 sports (men's football, women's field hockey, women's volleyball, men's baseball, women's softball, men's and women's basketball, men's and women's lacrosse, and men's and women's soccer) during the 2009–2010 through 2014–2015 academic years.

Patients or Other Participants: Collegiate student-athletes participating in 11 sports.

Main Outcome Measure(s): Ball-contact–injury rates, proportions, rate ratios, and proportion ratios with 95% confidence intervals were based on data from the NCAA Injury Surveillance Program during the 2009–2010 through 2014–2015 academic years.

Results: During the 2009–2010 through 2014–2015 academic years, 1123 ball-contact injuries were reported, for an overall rate of 3.54/10 000 AEs. The sports with the highest rates were women's softball (8.82/10 000 AEs), women's field hockey (7.71/10 000 AEs), and men's baseball (7.20/10 000 AEs). Most ball-contact injuries were to the hand/wrist (32.7%) and head/face (27.0%) and were diagnosed as contusions (30.5%), sprains (23.1%), and concussions (16.1%). Among sex-comparable sports (ie, baseball/softball, basketball, and soccer), women had a larger proportion of ball-contact injuries diagnosed as concussions than men (injury proportion ratio = 2.33; 95% confidence interval = 1.63, 3.33). More than half (51.0%) of ball-contact injuries were non-time loss (ie, participation-restriction time <24 hours), and 6.6% were severe (ie, participation-restriction time ≥21 days). The most common severe ball-contact injuries were concussions (n = 18) and finger fractures (n = 10).

Conclusion: Ball-contact–injury rates were the highest in women's softball, women's field hockey, and men's baseball. Although more than half were non–time-loss injuries, severe injuries such as concussions and fractures were reported.

Key Words: injury rates, injury prevention, protective equipment, head injuries, hand injuries

Key Points

- Ball-contact–injury rates were the highest in women's softball, women's field hockey, and men's baseball.
- To reduce ball-contact injuries, safety strategies including rule enforcement and improved protective equipment should be targeted during both practices and games.

More than 460 000 student-athletes compete in National Collegiate Athletic Association (NCAA)-sanctioned sports annually.[1] Previous epidemiologic studies on collegiate sports-related injuries have shown that reported incidences vary by sport and event type.[2,3] In addition, continued efforts by the NCAA, its member institutions, and associated organizations have propelled changes to practice and competition policies, rules, training regimens, injury-prevention interventions, and equipment standards.[3–6]

Although many of these changes are associated with reducing the incidence of injury related to player-to-player contact and noncontact, few researchers have examined injuries resulting from ball contact. Previous investigators have focused on ball-contact–related injuries as part of a cluster of all equipment-related injuries[7–16] or a mechanism of more catastrophic injuries[17] or in soccer-related discussions pertaining to heading and concussions[18] and surface type.[19] However, ball contact may be a common injury mechanism in sports with gameplay that focuses on a ball (eg, baseball, softball). Ball contact may not typically result in catastrophic injuries, but these injuries may still restrict participation in sports.

Table 1. Ball-Contact–Injury Rates Among Student-Athletes by Sport: National Collegiate Athletic Association Injury Surveillance Program, 2009–2010 Through 2014–2015 Academic Years

Sport	Ball-Contact Injuries, No.	Percentage of All Injuries Within Sport	Annual National Estimated Ball-Contact Injuries,[a] No.	Rates per 10 000 Athlete-Exposures (95% Confidence Interval)			Competition Versus Practice Rate Ratio (95% Confidence Interval)
				Competition	Practice	Overall	
Men's football	86	0.8	366	1.19 (0.54, 1.83)	0.72 (0.56, 0.89)	0.77 (0.60, 0.93)	1.65 (0.91, 2.97)
Women's field hockey	38	18.7	272	22.86 (14.24, 31.48)	2.93 (1.20, 4.67)	7.71 (5.26, 10.16)	7.79 (3.87, 15.71)[c]
Women's volleyball	131	9.9	872	7.83 (5.57, 10.10)	5.87 (4.62, 7.11)	6.43 (5.33, 7.54)	1.34 (0.93, 1.91)
Men's baseball	163	16.8	1867	13.34 (10.87, 15.81)	3.58 (2.59, 4.56)	7.20 (6.09, 8.30)	3.73 (2.68, 5.20)[c]
Women's softball	187	18.6	1499	14.99 (12.31, 17.67)	5.08 (3.86, 6.30)	8.82 (7.56, 10.09)	2.95 (2.19, 3.98)[c]
Men's basketball	37	1.6	257	2.07 (0.95, 3.20)	1.06 (0.64, 1.48)	1.28 (0.87, 1.69)	1.96 (1.00, 3.84)
Women's basketball	55	3.4	372	3.60 (2.06, 5.14)	1.78 (1.18, 2.38)	2.20 (1.62, 2.79)	2.02 (1.17, 3.49)[c]
Men's lacrosse	64	6.1	329	4.87 (2.56, 7.19)	2.68 (1.91, 3.45)	3.04 (2.3, 3.79)	1.82 (1.04, 3.16)[c]
Women's lacrosse	62	8.8	263	6.76 (3.72, 9.80)	3.59 (2.52, 4.66)	4.19 (3.15, 5.24)	1.88 (1.10, 3.23)[c]
Men's soccer	113	7.3	941	10.61 (7.48, 13.75)	4.57 (3.49, 5.65)	5.87 (4.79, 6.95)	2.32 (1.59, 3.39)[c]
Women's soccer	187	8.2	1236	11.82 (9.18, 14.46)	5.39 (4.38, 6.40)	6.95 (5.95, 7.94)	2.19 (1.64, 2.93)[c]
Men's total[b]	313	6.5	3065	8.98 (7.63, 10.34)	2.77 (2.32, 3.22)	4.42 (3.93, 4.91)	3.25 (2.60, 4.05)[c]
Women's total[b]	429	8.7	3107	10.71 (9.29, 12.13)	4.00 (3.46, 4.54)	5.87 (5.32, 6.43)	2.68 (2.21, 3.23)[c]
Total	1123	4.7	8275	8.02 (7.32, 8.72)	2.42 (2.23, 2.61)	3.54 (3.33, 3.75)	3.31 (2.95, 3.73)[c]

[a] National estimates for sports do not sum to total due to rounding.
[b] Includes only sex-comparable sports (ie, baseball/softball, basketball, and soccer).
[c] Denotes statistical significance.

An examination of injuries related to ball contact is warranted to help guide future equipment and policy decision making. Therefore, using data from a sample of programs from 11 sports that reported to the NCAA Injury Surveillance Program (ISP) during the 2009–2010 through 2014–2015 academic years, we describe the epidemiology of ball-contact injuries. Our specific aims were to (1) estimate the rate of ball-contact injuries by sport, (2) examine the distribution of ball-contact injuries within each sport by body part injured, diagnosis, activity, and participation-restriction time, and (3) compare rates and distributions of ball-contact injuries in sex-comparable sports (eg, baseball/softball, basketball, soccer).

METHODS

The NCAA-ISP is a prospective surveillance program managed by the Datalys Center for Sports Injury Research and Prevention, Inc, an independent, nonprofit research organization. Data originated from the 2009–2010 through 2014–2015 academic years. This study was approved by the Research Review Board at the NCAA. The methods of the ISP have been previously described[20] but are briefly summarized here.

Data Collection

The NCAA-ISP used a convenience sample of NCAA varsity teams from 25 sports from all 3 divisions with athletic trainers (ATs) reporting injury data. The number of programs providing data varied by sport and year.[20] The ATs working with participating teams attended NCAA-sanctioned competitions and practices, logging the number of student-athletes participating in each practice and competition. Injuries were reported in real time via the electronic health record application used by the team medical staff throughout the academic year. In addition to injuries, the ISP also captured other sport-related adverse health events, such as illness, heat-related conditions, general medical conditions, and skin infections. Data included varsity-level competitions and practices and team conditioning sessions. Individual weight-lifting and conditioning sessions were excluded.

When an injury occurred, the AT completed a detailed injury-event report. Reports included information such as body site and diagnosis, mechanism (eg, player contact, surface contact, ball contact), event type (ie, competition or practice), and time loss. After initially entering injury data, the AT could return to view and update the data as needed over the course of a season, such as when the student-athlete returned to sport participation (ie, time loss).

Deidentified common data elements (CDEs) were extracted from certified electronic health record applications.[20] The CDEs included injury and exposure information and were encrypted before being exported to the central aggregate research database. This CDE standard allowed ATs to document injuries normally as part of their daily clinical practice, as opposed to having them separately report injuries for ISP purposes.

Exported data passed through an automated verification process that conducted a series of range and consistency checks. Data were reviewed and invalid values flagged. The AT and data quality-assurance staff were notified and worked together to resolve the concerns. Data that passed

Table 2. Body Sites of Ball-Contact Injuries Among Student-Athletes by Sport: National Collegiate Athletic Association Injury Surveillance Program, 2009–2010 Through 2014–2015 Academic Years

Sport	Body Site, No. (%)												
	Head/Face	Neck	Shoulder	Arm/Elbow	Hand/Wrist	Trunk	Hip/Thigh/Upper Leg	Knee	Lower Leg	Ankle	Foot/Toes	Other	Total
Men's football	1 (1.2)	0	1 (1.2)	0	67 (77.9)	1 (1.2)	9 (10.5)	5 (5.8)	0	0	2 (2.3)	0	86 (100.0)
Women's field hockey	10 (26.3)	1 (2.6)	1 (2.6)	2 (5.3)	11 (28.9)	0	1 (2.6)	4 (10.5)	2 (5.3)	3 (7.9)	3 (7.9)	0	38 (100.0)
Women's volleyball	41 (31.3)	1 (0.8)	1 (0.8)	7 (5.3)	79 (60.3)	0	0	0	0	1 (0.8)	1 (0.8)	0	131 (100.0)
Men's baseball	32 (19.6)	0	4 (2.5)	28 (17.2)	37 (22.7)	5 (3.1)	10 (6.1)	3 (1.8)	22 (13.5)	3 (1.8)	18 (11.0)[a]	1 (0.6)	163 (100.0)
Women's softball	70 (37.4)[b]	0	3 (1.6)	20 (10.7)	40 (21.4)	5 (2.7)	9 (4.8)	6 (3.2)	25 (13.4)	4 (2.1)	5 (2.7)	0	187 (100.0)
Men's basketball	1 (2.7)	0	0	0	32 (86.5)	0	0	0	0	3 (8.1)	1 (2.7)	0	37 (100.0)
Women's basketball	11 (20.0)[b]	0	1 (1.8)	0	42 (76.4)	0	0	0	0	1 (1.8)	0	0	55 (100.0)
Men's lacrosse	20 (31.3)	3 (4.7)	0	2 (3.1)	9 (14.1)	11 (17.2)	5 (7.8)	2 (3.1)	2 (3.1)	8 (12.5)	0	2 (3.1)	64 (100.0)
Women's lacrosse	28 (45.2)	1 (1.6)	0	2 (3.2)	8 (12.9)	3 (4.8)	4 (6.5)	3 (4.8)	5 (8.1)	7 (11.3)	1 (1.6)	0	62 (100.0)
Men's soccer	21 (18.6)	1 (0.9)	0	3 (2.7)	18 (15.9)	0	23 (20.4)[a]	13 (11.5)	5 (4.4)	17 (15.0)	10 (8.8)[a]	2 (1.8)	113 (100.0)
Women's soccer	68 (36.4)[b]	2 (1.1)	1 (0.5)	5 (2.7)	24 (12.8)	5 (2.7)	14 (7.5)	26 (13.9)	3 (1.6)	34 (18.2)	5 (2.7)	0	187 (100.0)
Men's total[c]	54 (17.3)	1 (0.3)	4 (1.3)	31 (9.9)[a]	87 (27.8)	5 (1.6)	33 (10.5)[a]	16 (5.1)	27 (8.6)	23 (7.3)	29 (9.3)[a]	3 (1.0)	313 (100.0)
Women's total[c]	149 (34.7)[b]	2 (0.5)	5 (1.2)	25 (5.8)	106 (24.7)	10 (2.3)	23 (5.4)	32 (7.5)	28 (6.5)	39 (9.1)	10 (2.3)	0	429 (100.0)
Total	303 (27.0)	9 (0.8)	12 (1.1)	69 (6.1)	367 (32.7)	30 (2.7)	75 (6.7)	62 (5.5)	64 (5.7)	81 (7.2)	46 (4.1)	5 (0.4)	1123 (100.0)

[a] The proportion of injuries in men was greater than that in women (baseball/softball, basketball, soccer, and men's and women's totals only).
[b] The proportion of injuries in women was greater than that in men (baseball/softball, basketball, soccer, and men's and women's totals only).
[c] Includes only sex-comparable sports (ie, baseball/softball, basketball, and soccer).

the verification process were then placed into the aggregate research dataset.

Definitions

Injury. A reportable *injury* occurred as a result of participation in an organized intercollegiate practice or competition and required the attention of an AT or physician. Multiple injuries could be included as the result of 1 injury event.

Athlete-Exposure. A reportable *athlete-exposure* (AE) was defined as 1 student-athlete participating in 1 NCAA-sanctioned competition or practice in which he or she was exposed to the possibility of athletic injury, regardless of the time associated with that participation. Only athletes with actual playing time in a competition were included in competition exposures.

Event Type. *Event type* was the specific event (ie, competition, practice) in which the injury was reported to have occurred.

Injury Mechanism. *Injury mechanism* was defined as the manner in which the student-athlete sustained the injury. In the NCAA-ISP, ATs selected from a preset list of options: player contact, surface contact, equipment contact, contact with out-of-bounds object, noncontact, overuse, illness, infection, and other/unknown. When selecting *equipment contact*, ATs then specified the particular equipment (eg, contact with ball in baseball, contact with boards in ice hockey, contact with tackling dummy in football).

Injury Activity. *Injury activity* was defined as the specific activity that the student-athlete was performing when he or she sustained the injury. In the NCAA-ISP, ATs selected from a preset list of options specific to each sport.

Participation-Restriction Time. Injuries were categorized by the number of days of participation restriction (ie, date of injury subtracted from the date of return). *Non–time-loss (NTL) injuries* resulted in participation-restriction of less than 24 hours. *Severe injuries*[21] resulted in participation restriction of more than 3 weeks, the student-athlete choosing to prematurely end the season (for medical or nonmedical reasons associated with the injury), or a medical professional requiring the student-athlete to prematurely end the season.

Data Inclusion

For this study, we focused solely on those sports that use a ball in gameplay (men's football, women's field hockey, women's volleyball, men's baseball, women's softball, men's and women's basketball, men's and women's lacrosse, and men's and women's soccer). We then restricted analyses to only those injuries that were specified by ATs as occurring due to ball contact.

Computing National Estimates

To calculate national estimates of the number of ball-contact injuries, we applied poststratification sample weights based on sport, division, and academic year to each reported injury and AE.[20] Poststratification sample weights were calculated using the formula

Table 3. Diagnoses of Ball-Contact Injuries Among Student-Athletes by Sport: National Collegiate Athletic Association Injury Surveillance Program, 2009–2010 Through 2014–2015 Academic Years

Sport	Diagnosis, No. (%)								
	Concussion	Contusion	Dislocation	Fracture	Laceration	Sprain	Strain	Other	Total
Men's football	1 (1.2)	6 (7.0)	25 (29.1)	9 (10.5)	5 (5.8)	22 (25.6)	13 (15.1)	5 (5.8)	86 (100.0)
Women's field hockey	3 (7.9)	27 (71.1)	0	5 (13.2)	1 (2.6)	0	0	2 (5.3)	38 (100.0)
Women's volleyball	36 (27.5)	7 (5.3)	3 (2.3)	7 (5.3)	0	55 (42.0)	16 (12.2)	7 (5.3)	131 (100.0)
Men's baseball	10 (6.1)	113 (69.3)	0	17 (10.4)	4 (2.5)	3 (1.8)	2 (1.2)	14 (8.6)	163 (100.0)
Women's softball	32 (17.1)[a]	112 (59.9)	2 (1.1)	20 (10.7)	5 (2.7)	6 (3.2)	1 (0.5)	9 (4.8)	187 (100.0)
Men's basketball	0	1 (2.7)	8 (21.6)	4 (10.8)	0	22 (59.5)	1 (2.7)	1 (2.7)	37 (100.0)
Women's basketball	8 (14.5)	5 (9.1)	5 (9.1)	7 (12.7)	1 (1.8)	23 (41.8)	4 (7.3)	2 (3.6)	55 (100.0)
Men's lacrosse	10 (15.6)	30 (46.9)	2 (3.1)	8 (12.5)	2 (3.1)	10 (15.6)	0	2 (3.1)	64 (100.0)
Women's lacrosse	15 (24.2)	25 (40.3)	0	6 (9.7)	2 (3.2)	9 (14.5)	1 (1.6)	4 (6.5)	62 (100.0)
Men's soccer	15 (13.3)	4 (3.5)	4 (3.5)	6 (5.3)	0	37 (32.7)	33 (29.2)[b]	14 (12.4)	113 (100.0)
Women's soccer	51 (27.3)[a]	13 (7.0)	0	6 (3.2)	0	72 (38.5)	21 (11.2)	24 (12.8)	187 (100.0)
Men's total[c]	25 (8.0)	118 (37.7)[b]	12 (3.8)	27 (8.6)	4 (1.3)	62 (19.8)	36 (11.5)[b]	29 (9.3)	313 (100.0)
Women's total[c]	91 (21.2)[a]	130 (30.3)	7 (1.6)	33 (7.7)	6 (1.4)	101 (23.5)	26 (6.1)	35 (8.2)	429 (100.0)
Total	181 (16.1)	343 (30.5)	49 (4.4)	95 (8.5)	20 (1.8)	259 (23.1)	92 (8.2)	84 (7.5)	1123 (100.0)

[a] The proportion of injuries in women was greater than that in men (baseball/softball, basketball, soccer, and men's and women's totals only).
[b] The proportion of injuries in men was greater than that in women (baseball/softball, basketball, soccer, and men's and women's totals only).
[c] Includes only sex-comparable sports (ie, baseball/softball, basketball, and soccer).

$$\text{weight}_{ijk} = \left(\frac{\text{number of teams participating in ISP}_{ijk}}{\text{number of teams in NCAA}_{ijk}}\right)^{-1},$$

where weight_{ijk} is the weight for the *i*th sport of the *j*th division in the *k*th year. Weights for all data were further adjusted to correct for underreporting, according to findings of Kucera et al,[22] who estimated that the ISP captured 88.3% of all time-loss medical-care injury events. Weighted counts were scaled up by a factor of $(0.883)^{-1}$.

Statistical Analysis

Data were analyzed to assess rates and patterns of ball-contact injuries sustained in 11 collegiate sports. We first calculated rates, both overall and by event type. We then examined distributions of injuries by body part, diagnosis, injury activity (within each sport only and not overall), and time loss. For baseball and softball, we also explored specific ball-contact–related mechanisms that provided additional information on the type of ball contact (ie, hit by ground ball, line drive, foul ball, pitch, thrown ball [nonpitch]); such information was not available for other sports. Last, national estimates were calculated per sport.

Injury rate ratios (IRRs) compared ball-contact rates within sports by event type (ie, competition or practice). Rate ratios and injury proportion ratios (IPRs) also compared rates and distributions, respectively, for sex-comparable sports (ie, baseball/softball, basketball, soccer). For participation-restriction time, only the proportions of injuries that were NTL or severe were examined.

The following is an example of an IRR comparing competition and practice ball-contact–injury rates:

$$\text{IRR} = \frac{\left(\frac{\sum \text{competition ball-contact injuries}}{\sum \text{competition AEs}}\right)}{\left(\frac{\sum \text{practice ball-contact injuries}}{\sum \text{practice AEs}}\right)}.$$

The following is an example of an IPR comparing the proportion of ball-contact injuries that affected the head/face in men and women:

$$\text{IPR} = \frac{\left(\frac{\sum \text{head/face ball-contact injuries in men}}{\sum \text{total ball-contact injuries in men}}\right)}{\left(\frac{\sum \text{head/face ball-contact injuries in women}}{\sum \text{total ball-contact injuries in women}}\right)}.$$

All 95% confidence intervals (CIs) not including 1.00 were considered statistically significant. Data were analyzed using SAS Enterprise Guide software (version 4.3; SAS Institute, Cary, NC).

RESULTS

Overall Frequencies, Rates, and National Estimates

During the 2009–2010 through 2014–2015 academic years, ATs in participating programs reported 23 710 injuries in the 11 sports we studied. Of these injuries, 1123 (4.7% of the total) were due to ball contact. Slightly more ball-contact injuries occurred during practices (n = 614, 54.7%); however, the percentage of ball-contact injuries during competitions was higher in women's field hockey (n = 27, 71.1%), men's baseball (n = 112, 68.7%), and women's softball (n = 120, 64.2%). The 1123 ball-contact injuries were sustained across 3 172 736 AEs, leading to an overall rate of 3.54/10 000 AEs (Table 1). The sports with the largest overall ball-contact–injury rates were women's softball (8.82/10 000 AEs), women's field hockey (7.71/10 000 AEs), and men's baseball (7.20/10 000 AEs). Overall, the ball-contact–injury rate was higher in competition than in practice (8.02 versus 2.42/10 000 AEs; IRR = 3.31; 95% CI = 2.95, 3.73). Competition rates were also higher than practice rates in all sports except men's basketball, football, and women's volleyball (although these effect estimates were all greater than 1.00, indicating a trend toward competitions having higher rates than practices). Within sex-comparable sports, women had a higher overall ball-contact–injury rate than men (IRR = 1.33; 95% CI = 1.15, 1.54); however, this difference was attributable to basketball only (IRR = 1.72; 95% CI = 1.14, 2.62), whereas

Table 4. Common Activities Associated With Ball-Contact Injuries Among Student-Athletes by Sport: National Collegiate Athletic Association Injury Surveillance Program, 2009–2010 Through 2014–2015 Academic Years

Sport and Activity	No. (%)
Men's football	
Receiving a pass	43 (50.0)
General play	21 (24.4)
Kicking	17 (19.8)
Women's field hockey	
Defending	17 (44.7)
General play	6 (15.8)
Blocking shots	5 (13.2)
Women's volleyball	
Blocking	55 (42.0)
Digging	22 (16.8)
General play	15 (11.5)
Men's baseball	
Batting	86 (52.8)
Pitching	25 (15.3)
Fielding	25 (15.3)
Women's softball	
Batting	67 (35.8)
Fielding	46 (24.6)
Pitching	29 (15.5)
Men's basketball	
Receiving a pass	10 (27.0)
General play	10 (27.0)
Rebounding	7 (18.9)
Women's basketball	
Receiving a pass	20 (36.4)
Defending	10 (18.2)
Men's lacrosse	
Goaltending	17 (26.6)
Defending	15 (23.4)
Blocking shots	14 (21.9)
Women's lacrosse	
Goaltending	13 (21.0)
Defending	11 (17.7)
Blocking shots	9 (14.5)
Men's soccer	
Blocking shots	20 (17.7)
General play	20 (17.7)
Goaltending	15 (13.3)
Women's soccer	
Defending	34 (18.2)
General play	34 (18.2)
Blocking shots	26 (13.9)

no sex differences were found for soccer (IRR = 1.18; 95% CI = 0.94, 1.50) or baseball/softball (IRR = 1.23; 95% CI = 0.99, 1.51).

The 1123 ball-contact injuries represent a national estimate of 49 658 ball-contact injuries sustained over the past 6 years, or approximately 8275 injuries annually (Table 1). The sports with the highest national estimates were men's baseball (n = 1867), women's softball (n = 1499), and women's soccer (n = 1236). Despite having the second highest ball-contact–injury rate, women's field hockey had the third lowest annual national estimate (n = 272).

Body Part Injured

Overall, most ball-contact injuries affected the hand/wrist (n = 367, 32.7%) and head/face (n = 253, 27.0%; Table 2). Within specific sports were some discrepancies from the overall findings. For example, in men's soccer, large proportions of ball-contact injuries were sustained to the hip/thigh/upper leg (n = 23, 20.4%); in women's soccer, large proportions were sustained to the ankle (n = 34, 18.2%). Among sex-comparable sports, women had a larger proportion of ball-contact injuries than men to the head/face (IPR = 1.84; 95% CI = 1.45, 2.32); in contrast, men had larger proportions of ball-contact injuries to the arm/elbow (IPR = 1.70; 95% CI = 1.02, 2.82), hip/thigh/upper leg (IPR = 1.83; 95% CI = 1.14, 2.95), and foot/toes (IPR = 3.43; 95% CI = 1.74, 6.78) than women. Injury proportion differences varied by sex-comparable sport pair; however, all 3 pairs demonstrated a higher proportion of injuries to the head/face in women than in men.

Diagnosis

Overall, most ball-contact injuries were diagnosed as contusions (n = 343, 30.5%), sprains (n = 259, 23.1%), or concussions (n = 181, 16.1%; Table 3). Within specific sports were some discrepancies from overall findings. For example, in men's football, large proportions of ball-contact injuries were diagnosed as dislocations (n = 25, 29.1%), most of which were to the fingers (n = 24); in men's soccer, large proportions were diagnosed as strains (n = 33, 29.2%), of which most were to the hip/thigh/upper leg (n = 22). Among sex-comparable sports, women had a larger proportion of ball-contact injuries diagnosed as concussions than men (IPR = 2.33; 95% CI = 1.63, 3.33); in contrast, compared with women, men had larger proportions of ball-contact injuries diagnosed as contusions (IPR = 1.24; 95% CI = 1.02, 1.52) and strains (IPR = 1.90; 95% CI = 1.17, 3.08). Injury proportion differences varied by sex-comparable sport pair; however, all 3 pairs displayed a higher proportion of injuries diagnosed as concussion in women than in men (0 concussions were reported in men's basketball).

Injury Activity

Ball-contact injuries occurred from a variety of activities specific to each sport (Table 4).

Although it was not as common as other activities, in men's and women's soccer, heading was associated with 7 (6.2%) and 24 (12.8%) ball-contact injuries, respectively. Of these injuries, 4 and 18, respectively, were concussions (57.1% and 75.0%, respectively, of all heading injuries).

Baseball/Softball-Specific Ball-Contact Mechanisms

In baseball and softball, most ball-contact injuries were due to being hit by a pitch (baseball: n = 70, 42.9%; softball: n = 54, 28.9%) or by a line drive (baseball: n = 34, 20.9%; softball: n = 46, 24.6%; Figure). The proportion of ball-contact injuries due to being hit by a pitch was higher in baseball than in softball (IPR = 1.49; 95% CI = 1.12, 1.98); however, in both sports, most of these injuries were arm/elbow contusions (baseball: n = 19; softball: n = 12) and hand/wrist contusions (baseball: n = 17; softball: n = 11).

Participation-Restriction Time

Overall, slightly more than half of ball-contact injuries were NTL (n = 573, 51.0%) and 6.6% (n = 74) were severe (Table 5). The sports with the largest proportions of ball-

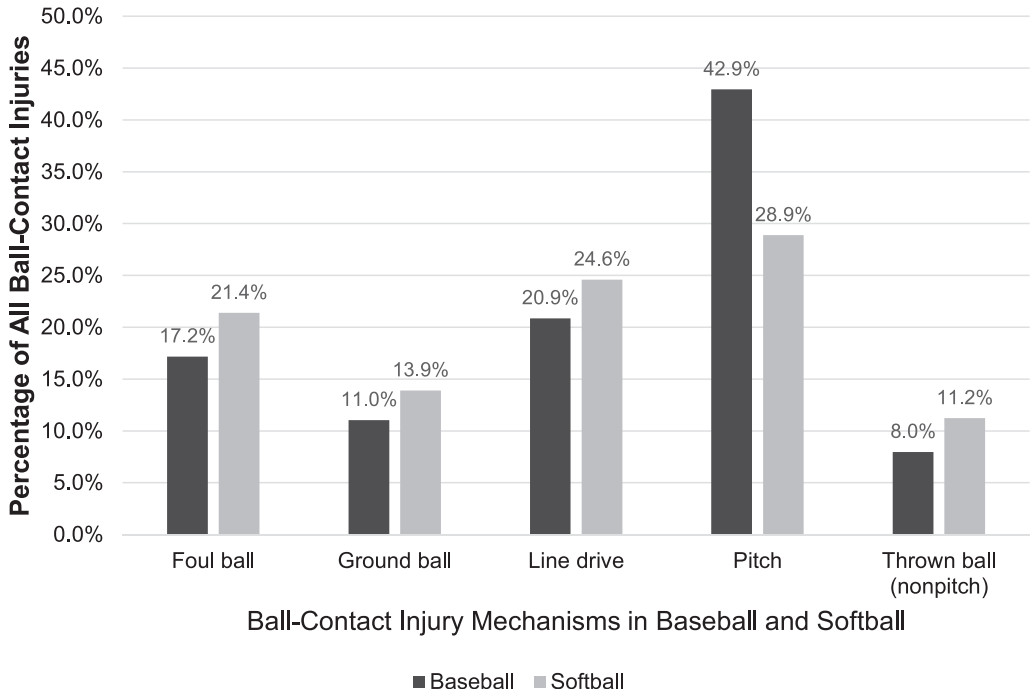

Figure. Distribution of specific ball-contact–injury mechanisms among baseball and softball student-athletes: National Collegiate Athletic Association Injury Surveillance Program, 2009-2010 through 2014–2015 academic years.

contact injuries that were NTL were men's basketball (n = 28, 75.7%), men's football (n = 59, 68.6%), men's baseball (n = 109, 66.9%), and women's field hockey (n = 25, 65.8%). The sports with the largest proportions of ball-contact injuries that were severe were men's soccer (n = 14, 12.4%), women's basketball (n = 6, 10.9%), and women's soccer (n = 17, 9.1%). The type of severe ball-contact injuries varied by sport (Table 6) with the most common being concussions (n = 18) and finger fractures (n = 10). Among sex-comparable sports, men had a larger proportion of ball-contact injuries that were NTL than women (IPR = 1.17; 95% CI = 1.02, 1.34); no difference in the proportion of ball-contact injuries that were severe was evident between men and women (IPR = 0.58; 95% CI = 0.25, 1.32). Injury proportion differences varied per sex-comparable sport pair.

DISCUSSION

Although ball-contact injuries occurred across multiple sports, we found the highest rate in baseball, as posited by previous researchers,[23] followed by softball and field hockey. In addition, even though slightly more than half of ball-contact injuries were NTL, a number of severe injuries occurred, many of which were concussions and finger fractures. No authors have specifically investigated injuries caused by ball contact in sports except for soccer, but other mechanisms, including player-to-player injuries in colle-

Table 5. Participation-Restriction Time Associated With Ball-Contact Injuries Among Student-Athletes by Sport: National Collegiate Athletic Association Injury Surveillance Program, 2009–2010 Through 2014–2015 Academic Years

Sport	Participation-Restriction Time, d, No. (%)					
	<1 (Non–Time-Loss Injury)	1–6	7–21	>21 (Severe Injury)	Missing	Total
Men's football	59 (68.6)	17 (19.8)	4 (4.7)	3 (3.5)	3 (3.5)	86 (100.0)
Women's field hockey	25 (65.8)	7 (18.4)	4 (10.5)	2 (5.3)	0	38 (100.0)
Women's volleyball	72 (55.0)	30 (22.9)	21 (16.0)	5 (3.8)	3 (2.3)	131 (100.0)
Men's baseball	109 (66.9)	28 (17.2)	13 (8.0)	9 (5.5)	4 (2.5)	163 (100.0)
Women's softball	94 (50.3)[a]	45 (24.1)	33 (17.6)	9 (4.8)	6 (3.2)	187 (100.0)
Men's basketball	28 (75.7)	5 (13.5)	3 (8.1)	1 (2.7)	0	37 (100.0)
Women's basketball	31 (56.4)	12 (21.8)	3 (5.5)	6 (10.9)	3 (5.5)	55 (100.0)
Men's lacrosse	19 (29.7)	26 (40.6)	10 (15.6)	6 (9.4)	3 (4.7)	64 (100.0)
Women's lacrosse	33 (53.2)	15 (24.2)	10 (16.1)	2 (3.2)	2 (3.2)	62 (100.0)
Men's soccer	41 (36.3)	37 (32.7)	20 (17.7)	14 (12.4)	1 (0.9)	113 (100.0)
Women's soccer	62 (33.2)	54 (28.9)	47 (25.1)	17 (9.1)	7 (3.7)	187 (100.0)
Men's total[b]	178 (56.9)	70 (22.4)	36 (11.5)	24 (7.7)	5 (1.6)	313 (100.0)
Women's total[b]	187 (43.6)[a]	111 (25.9)	83 (19.3)	32 (7.5)	16 (3.7)	429 (100.0)
Total	573 (51.0)	276 (24.6)	168 (15)	74 (6.6)	32 (2.8)	1123 (100.0)

[a] The proportion of injuries in women was greater than that in men (baseball/softball, basketball, soccer, and men's and women's totals only).

[b] Includes only sex-comparable sports (ie, baseball/softball, basketball, and soccer).

Table 6. Severe Injuries Sustained Due to Ball Contact Among Student-Athletes by Sport: National Collegiate Athletic Association Injury Surveillance Program, 2009–2010 Through 2014–2015 Academic Years[a]

Sport and Severe Injury	No.
Men's football	
Hip fracture	1
Hip flexor strain	1
Finger sprain	1
Women's field hockey	
Hand contusion	1
Finger fracture	1
Women's volleyball	
Concussion	3
Finger fracture	2
Men's baseball	
Hand/wrist fracture	3
Toe fracture	2
Radial fracture	1
Facial fracture	1
Other injury	2
Women's softball	
Finger fracture	4
Facial fracture	3
Concussion	1
Facial laceration	1
Men's basketball	
Finger sprain	1
Women's basketball	
Concussion	3
Finger fracture	2
Finger strain	1
Men's lacrosse	
Jaw fracture	4
Concussion	1
Finger fracture	1
Women's lacrosse	
Concussion	2
Men's soccer	
Concussion	3
Knee sprain	2
Hip fracture	1
Ankle sprain	1
Ankle fracture	1
Foot sprain	1
Other injury	5
Women's soccer	
Concussion	5
Knee sprain	4
Radial fracture	2
Ankle sprain	2
Hip fracture	1
Other injury	3

[a] *Severe injury* was defined as resulting in participation restriction of more than 3 weeks, the student-athlete choosing to prematurely end the season (for medical or nonmedical reasons associated with the injury), or a medical professional requiring the student-athlete to prematurely end the season.

giate[24] and high school sports, have been reported.[25] This is the first study, to our knowledge, to examine the rates and patterns of ball-contact injuries in 11 collegiate sports. The incidence of ball-contact injuries is less than the incidences related to player-to-player contact and noncontact,[3] yet the findings highlight the need to consider equipment modifications that will not drastically affect gameplay but will help to reduce the incidence and severity of ball-contact injuries.

Variations in Ball-Contact–Injury Incidence by Sport

Aside from baseball, softball, and field hockey having the highest ball-contact–injury rates, they were also the only sports of the 11 examined that had higher proportions of such injuries in competitions versus practices (range of 64.2%–71.1%). Previous researchers[2,3] have suggested that, although injury rates are higher during competitions than during practices, more time is spent in practice sessions, leading to a larger reported number of injuries in practices than in competitions. These findings merit the implementation of injury-prevention strategies in both types of events to reduce incident injuries. In 8 of the 11 sports included in this study, more injuries occurred during practices than during competitions, supporting the aforementioned study suggestions. Implementing injury-prevention strategies during practices, which are controlled environments focused on skills development and preparation for future competitions, may be beneficial in reducing the incidence of ball-contact injuries in both competitions and practices. However, given the higher rates and reported frequencies in competitions in sports such as basketball, lacrosse, and soccer, our best chances of reducing ball-contact injuries may be in targeting competitions through rule enforcement and changes and improved protective equipment.

The variations in ball-contact–injury rates by sport may be attributable to the type of ball used in each. Football, which typically has the highest injury rate across all sports,[2,3,26] had the lowest competition, practice, and overall ball-contact–injury rates among the 11 sports included in this study (1.19, 0.72, and 0.77/10 000 AEs, respectively). Basketball also had lower ball-contact–injury rates than other sports. The various ball shapes (round, oblong), materials, mass, density, and potential ranges in velocity for each ball-related sport are important considerations (Table 7). Basketballs are the largest, are of medium density when filled to their respective pounds per square inch of air, and arguably have the lowest average velocities compared with all other balls included in this study, resulting in a reduced injury risk. Meanwhile, balls in other sports are denser and may move at faster velocities. The 5 sports in this study that use a stick or bat are associated with significantly higher ball velocities due to the longer lever arms provided by the stick or bat length. These sports also use small, high-density balls that, when moving at high velocities, have the potential to cause severe injuries to unpadded, vulnerable body parts (head/face, hands). This may also be illustrated by the specific ball-contact mechanisms in baseball and softball. Most injuries were due to being hit by pitches or line drives, which are typically when the ball is moving the fastest. To better ascertain injury risk as related to ball contact, future researchers should consider more in-depth examinations of ball types across sports, the various manners in which ball contact can occur within sports, and the effect of protective equipment type and placement on ball-contact–injury incidence.

Sex Differences

Previous investigations[2,3,25,27,28] of all injuries as well as specific types of injuries or injury mechanisms have demonstrated sex differences in injury rates. However, among ball-contact injuries, the only sport displaying sex differences was basketball, although sex differences were

Table 7. National Collegiate Athletic Association Ball Specifications by Sport

Sport	Circumference (in)	Shape	Outer Material	Inner Material	Mass (oz)	Density
Men's football	28.0 (wide), 21.0 (long)	Oblong	Leather	Air	14–16	Medium
Women's field hockey	8.8–9.3	Sphere	Plastic	Cork core[a]	5.5–5.7	Hard
Women's volleyball	25.5–26.5	Sphere	Leather	Air	9.2–9.9	Soft
Men's baseball	9–9.25	Sphere	Leather	Yarn or string around a rubber or cork center	5.0–5.25	Hard
Women's softball	12.0	Sphere	Leather	Kapok, mixture of cork and rubber, or polyurethane mixture	6.25–7.0	Hard
Men's basketball	29.5–30	Sphere	Leather	Air	22	Medium
Women's basketball	28–29	Sphere	Leather	Air	20	Medium
Men's lacrosse	7.75–8.0	Sphere	Rubber	Solid rubber	5.0–5.25	Hard
Women's lacrosse	7.75–8.0	Sphere	Rubber	Solid rubber	5.0–5.25	Hard
Men's soccer	27–28.0	Sphere	Leather	Air	14.0–16.0	Soft
Women's soccer	27–28.0	Sphere	Leather	Air	14.0–16.0	Soft

[a] Optional.

found across all 3 pairs of sex-comparable sports. These differences may be due to variations between men's and women's offensive and defensive strategies, practice and competition facilities, gameplay intensity, types of practice sessions, and willingness to report injuries. In particular, the most consistent findings across all 3 pairs of sex-comparable sports were that the proportion of injuries that were diagnosed as concussions and affected the head/face was higher in women than in men. Earlier authors suggested that women may be more likely to disclose concussions than men[29–31] and that sports medicine professionals may be likely to treat head injuries more conservatively,[29] thus leading to more diagnoses. The fact that we found this sex difference in concussion incidence in our exclusive examination of ball-contact injuries may suggest that such differences are not associated with particular injury mechanisms. Nevertheless, more research is warranted to better understand sex differences related to concussion incidence based on other forms of contact (eg, player-to-player contact, player-to-surface contact).

Protective Equipment to Reduce the Risk of Ball-Contact Injuries

Given the diversity in the data related to ball-contact injuries, it is important to address the efficacy of protective equipment. The head/face accounted for more than a quarter of all ball-contact injuries in the study. This percentage was lower in football, which is a helmeted sport (Table 8). However, large proportions were nonetheless reported in other sports that use helmets, such as men's lacrosse. It should be noted that the proportion of head/face injuries in women's lacrosse, which does not require helmet use, was the highest of all the sports we studied. In addition, other sports with high proportions of injuries to the head/face do not consistently require helmets, such as baseball, softball (eg, batters), and field hockey (eg, goaltenders). For baseball and softball players, faceguards may be of benefit to reduce the risk of head/face ball-contact injuries, particularly because many maxillofacial injuries are ball related.[32] Faceguards have been shown to result in a reduced risk of facial injuries in youth baseball players (ages 5–18 years).[33] In a similar study of baseball players ranging from less than 5 to greater than 64 years of age, faceguards were more effective in younger players due to less frequent use in older athletes.[34] These changes should be investigated more thoroughly to determine if their implementation would reduce the ball-contact–injury risk in these athletes. Additionally, our findings elicit the need for further discussion about helmet use to mitigate the injury risk related to ball-contact injuries.

Helmet standards have been adequately addressed in football. However, discussion of protective headgear for other sports is limited. For example, the National Operating

Table 8. National Collegiate Athletic Association Required Equipment by Sport

	Required Equipment									
Sport	Helmet	Facemask	Eye Protection (Goggles)	Throat Guard	Shoulder Pads	Chest/Abdominal Padding	Leg Pads	Gloves	Mouth Guard	Stick/Bat
Men's football	A	A			A		A	A[a]	A	
Women's field hockey	G	G	A	G[a]	G	G	G	G	A	A
Women's volleyball										
Men's baseball	C/O	C		C[a]		C	O[a]/C	O[a]/D		O
Women's softball	C/O	O[a]/C		C[a]		C	C	O[a]/D		O
Men's basketball									A[a]	
Women's basketball									A[a]	
Men's lacrosse	A	A		G[a]	A	G	G	A	A	A
Women's lacrosse	G	G	A	G[a]	G	G	G	A[a]/G	A	A
Men's soccer							A	G		
Women's soccer							A	G		

Abbreviations: A, all athletes; C, catchers; D, defensive players (specific to baseball and softball, includes catchers); G, goalies only; O, offensive players (specific to baseball and softball).

[a] Optional equipment but often used for the referenced group.

Committee on Standards for Athletic Equipment does provide specific certification standards that must be met before men's lacrosse helmets are used initially. However, to our knowledge, no current reconditioning rules exist for any level of men's lacrosse, men's baseball, or women's softball helmets. Due to this lack of standardization, these helmets may be worn beyond the materials' ability to protect the wearer. Baseball and softball helmet materials are typically flexible plastic with foam padding distributed through the crown and earflaps. It is not uncommon for a batter to sustain a concussion when hit in the helmet by a pitch. This was supported by a recent study[35]: the risk of concussion was high, regardless of which of 4 baseball helmets was tested using a Hybrid III headform.

Discussion of protective equipment must also acknowledge the potential consequences of equipment differences between men's and women's sports (Table 8). Men's collegiate football and lacrosse players wear helmets, shoulder pads, and facemasks, among other protective devices (gloves, elbow/forearm pads, etc). None of the women's sports in this study require more than goggles (women's lacrosse), except for goalkeepers in field hockey and lacrosse and batters and catchers in softball. The lack of mandatory protective equipment for these women's sports may elevate the athletes' risk for injuries. Increasing requirements for protective equipment in women's sports may reduce the incidence and severity of injury.

It is important to acknowledge that protective equipment is not 100% effective in preventing all injuries. Despite the mandatory use of helmets in football and lacrosse, gloves in lacrosse, and shin guards in soccer, injuries to the head/face, hand/wrist, and lower leg, respectively, were reported in these sports. However, it is possible that the protective equipment mitigated the injury severity. Although team medical staffs may be more conservative in returning injured female athletes to sport, the larger proportion of injuries that were NTL in men compared with women may also highlight a difference in the effectiveness of their equipment. Sport governing bodies should consider evaluating the current and additional use of protective equipment. Longitudinal prospective research is needed to examine the use of such protective equipment and its association with potential reductions in injury incidence.

Limitations

The data originated from a convenience sample of teams from 11 NCAA sports. As a result, our findings may not be generalizable to nonparticipating teams or to other sports or levels of competition. Although the injury data were reported by ATs, data collection regarding specific injury characteristics may have been provided to the ATs by the injured athletes; thus, it is possible that, in such cases, the data are not reliable. Exposure data do not account for variations in the time during which student-athletes are active during a competition or practice. However, our use of AEs is more feasible for the ATs who are collecting data while providing care to their student-athlete populations. Aside from baseball and softball, we were not able to examine specific ball-contact–related injury mechanisms. Such information would better identify target areas for injury prevention. Despite these limitations, we believe that the importance of these data is greater than the limitations acknowledged here, particularly because this is the first large study to our knowledge that describes the epidemiology of ball-contact injuries in NCAA sports.

CONCLUSIONS

Ball-contact–injury rates were the highest in lacrosse and field hockey. Although more than half of the injuries were NTL, severe injuries such as concussions and fractures were also reported. We suggest that coaches, athletes, and athletic organizations strongly consider adopting more stringent rules and regulations for protective equipment in sports with a high risk of ball-contact injuries. Previous authors[23,33,34] have shown that adding cages to baseball and softball helmets significantly decreased face/head injuries. These same studies support additional protective equipment to reduce ball-related injuries, including eye shields for infielders and thoracic protections for pitchers. Implementing similar protective equipment to other sports that involve dense balls (eg, field hockey and lacrosse) could also reduce ball-contact injuries, particularly those related to the head/face and hand/wrist. Continued surveillance of ball-contact injuries and patterns is needed to improve player safety and determine more effective prevention strategies.

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