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Descriptive Epidemiology of Collegiate Women's Lacrosse Injuries: National Collegiate Athletic Association Injury Surveillance System, 1988–1989 Through 2003–2004

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Objective: To review 16 years of National Collegiate Athletic Association injury surveillance data for women's lacrosse and identify potential areas for injury prevention initiatives.

Background: Women's lacrosse is a fast-paced, primarily noncontact sport. Participation in collegiate women's lacrosse almost doubled between the 1988–1989 and 2003–2004 seasons. Lacrosse equipment consists of sticks made of wood or a synthetic material and a hard rubber ball. Until recently, mouth guards were the only required protective equipment.

Main Results: Collegiate women's lacrosse game injury rates increased over the 16-year study period. More than 60% of all severe game injuries were lower extremity sprains and strains and knee internal derangements, most frequently the result of noncontact incidents. The most common injury scenarios by injury mechanism and player activity were no contact while ball handling (16.4%) and contact from a stick while ball handling (10.5%). Contact from a stick or a ball accounted for 5.6% and 5.2% of injuries sustained during shooting activities, respectively. Approximately 22% of all game and 12% of all practice injuries involved the head and neck. Contact from a stick accounted for the majority (56.0%) of above-the-neck injuries in games; contact from the ball accounted for 20.0% of these injuries. Participants had 5 times the risk of sustaining a concussion in a game as in a practice (0.70 versus 0.15 injuries per 1000 athletic-exposures, rate ratio = 4.7, 95% confidence interval = 3.8, 6.5).

Recommendations: To reduce the lower extremity injuries that comprise the greatest injury burden in women's lacrosse, future researchers should evaluate proprioceptive, plyometric, and balance training interventions designed specifically for female players. Other research areas of great interest involve determining whether protective eyewear (mandated in 2004) reduces injuries to the eye, orbit, and nasal area and identifying any unintended consequences of the mandate, such as increased risk of injuries to other areas of the face or more aggressive play.

Key Words: athletic injuries, injury prevention, concussions, lower extremity injuries, knee injuries, facial injuries

The National Collegiate Athletic Association (NCAA) conducted its first women's lacrosse championship in 1982. In the 1988–1989 academic year, 119 schools sponsored varsity women's lacrosse teams, with a total of 2880 participants in the sport.[1] By the 2003–2004 season, the number of varsity teams had increased 119% to 261, involving 5545 participants. Sizeable participation growth during this time occurred in all 3 NCAA divisions.

SAMPLING AND METHODS

Over the 16-year period from 1988–1989 through 2003–2004, an average of 23.1% of schools sponsoring varsity women's lacrosse programs participated in annual NCAA Injury Surveillance System (ISS) data collection (Table 1). The sampling process, data collection methods, injury and exposure definitions, inclusion criteria, and data analysis methods are described in detail in the ''Introduction and Methods'' article in this special issue.[2]

RESULTS

Game and Practice Athlete-Exposures

The average annual number of games, practices, and athletes participating for each NCAA division, condensed over the study period, are shown in Table 2. Women's lacrosse programs in Divisions I, II, and III averaged 60, 55, and 48 practices per year, respectively. Division I teams played an average of 16 games per year, 2 games more than Division II and III teams. The average numbers of game and practice participants were similar in all divisions.

Injury Rate by Activity, Division, and Season

Game and practice injury rates across all divisions, with 95% confidence intervals (CIs), are displayed in Figure 1. Over the 16 years, the game injury rate was twice the rate for practice (7.15 versus 3.30 injuries per 1000 athlete-exposures [A-Es], rate ratio = 2.2, 95% CI = 2.0, 2.3). A significant

Table 1. School Participation Frequency (in Total Numbers) by Year and National Collegiate Athletic Association (NCAA) Division, Women's Lacrosse, 1988–1989 Through 2003–2004*

Academic year	Division I Schools		Division II Schools		Division III Schools		All Divisions		
	Participating	Sponsoring	Participating	Sponsoring	Participating	Sponsoring	Participating	Sponsoring	Percentage
1988–1989	7	33	1	13	16	72	24	119	20.2
1989–1990	5	34	2	12	9	73	16	120	13.3
1990–1991	9	33	3	12	20	73	32	118	27.1
1991–1992	8	34	4	10	16	78	28	122	23.0
1992–1993	6	35	3	11	17	80	26	126	20.6
1993–1994	5	37	3	12	24	84	32	133	24.1
1994–1995	7	40	5	12	23	92	35	145	24.1
1995–1996	12	47	4	15	26	102	42	164	25.6
1996–1997	15	56	3	19	32	108	50	183	27.3
1997–1998	13	60	4	22	23	119	40	201	19.9
1998–1999	5	66	3	23	21	124	29	213	13.6
1999–2000	8	71	1	24	30	130	39	225	17.3
2000–2001	37	71	1	26	27	141	65	238	27.3
2001–2002	39	75	5	28	24	146	68	249	27.3
2002–2003	39	77	6	29	38	150	83	256	32.4
2003–2004	35	77	4	32	28	149	67	261	25.7
Average	16	53	3	19	23	108	42	180	23.1

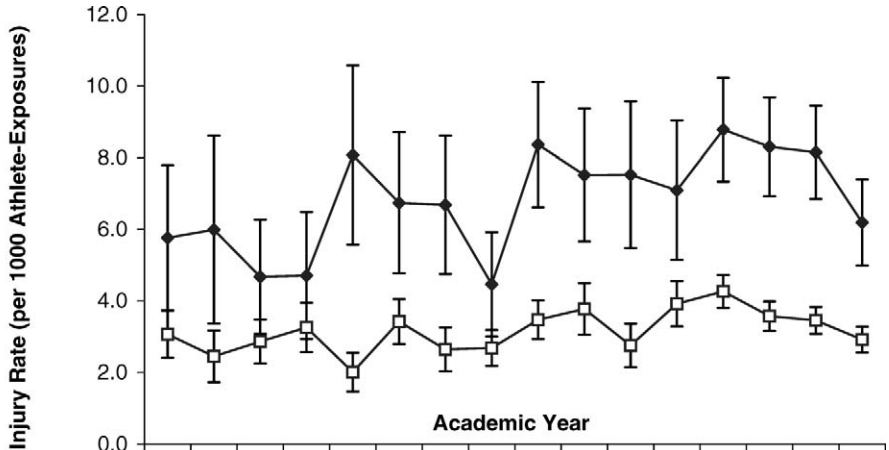
*"Participating" refers to schools that provided appropriate data to the NCAA Injury Surveillance System; "Sponsoring" refers to the total number of schools offering the sport within the NCAA divisions.

Table 2. Average Annual Games, Practices, and Athletes Participating by National Collegiate Athletic Association Division per School, Women's Lacrosse, 1988–1989 Through 2003–2004

Division	Games	Athletes per Game	Practices	Athletes per Practice
I	16	16	60	23
II	14	16	55	21
III	14	16	48	20

2.4% average annual increase in game injury rates was noted ($P = .02$), and a 1.6% average annual increase in practice injury rates was seen, although the latter finding was not statistically significant ($P = .08$).

The total numbers of games and practices and associated injury rates by division and time of season (preseason, in season, and postseason) are presented in Table 3. Over the 16-year period, 1066 injuries from more than 9000 games and 2326 injuries from more than 33 000 practices were reported. Game and practice injury rates were higher in Division I than in Division III (games: 8.56 versus 6.07 injuries per 1000



	88-89	89-90	90-91	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02	02-03	03-04
Game injury rate	5.8	6.0	4.7	4.7	8.1	6.7	6.7	4.5	8.4	7.5	7.5	7.1	8.8	8.3	8.1	6.2
Practice injury rate	3.1	2.5	2.9	3.3	2.0	3.4	2.6	2.7	3.5	3.8	2.8	3.9	4.3	3.6	3.5	2.9

Figure 1. Injury rates and 95% confidence intervals per 1000 athlete-exposures by games, practices, and academic year, women's lacrosse, 1988–1989 through 2003–2004 (n = 1066 game and 2326 practice injuries). Game time trend $P = .02$. Average annual change in game injury rate = 2.4% (95% confidence interval = 0.4, 4.4). Practice time trend $P = .08$. Average annual change in practice injury rate = 1.6% (95% confidence interval = −0.2, 3.4).

Table 3. Games and Practices With Associated Injury Rates by National Collegiate Athletic Association Division and Season, Women's Lacrosse, 1988–1989 Through 2003–2004*

	Total Games Reported, No.	Game Injury Rate	95% Confidence Interval	Total Practices Reported, No.	Practice Injury Rate	95% Confidence Interval
Division I						
Preseason	111	6.14	2.66, 9.61	6332	5.21	4.84, 5.59
In season	3418	8.73	7.96, 9.50	7132	2.73	2.47, 2.99
Postseason	154	6.40	3.26, 9.53	397	1.39	0.60, 2.17
Total Division I	3683	8.56	7.83, 9.29	13 861	3.85	3.63, 4.07
Division II						
Preseason	33	1.73	0.00, 5.12	1491	3.13	2.53, 3.74
In season	624	6.85	5.23, 8.46	1149	2.44	1.82, 3.06
Postseason	35	9.39	1.16, 17.62	69	3.02	0.06, 5.99
Total Division II	692	6.79	5.27, 6.79	2709	2.84	2.40, 3.27
Division III						
Preseason	172	6.28	3.38, 9.18	8939	3.53	3.26, 3.81
In season	4273	6.22	5.62, 6.81	7454	2.19	1.95, 2.43
Postseason	300	3.77	2.03, 5.51	559	0.64	0.17, 1.12
Total Division III	4745	6.07	5.51, 6.62	16 952	2.87	2.69, 2.87
All Divisions						
Preseason	316	5.74	3.72, 7.76	16 762	4.29	4.06, 4.51
In season	8315	7.32	6.87, 7.78	15 735	2.47	2.30, 2.64
Postseason	489	5.20	3.60, 6.90	1025	1.10	0.65, 1.55
Total	9179	7.15	6.73, 7.58	33 678	3.30	3.16, 3.43

*Wald χ^2 statistics from negative binomial model: game injury rates differed among divisions ($P = .05$) and within season ($P = .05$); practice injury rates differed among divisions ($P < .01$) and within season ($P < .01$). Postseason sample sizes are much smaller (and have a higher variability) than preseason and in season sample sizes because only a small percentage of schools participated in the postseason tournaments in any sport and not all of those were a part of the Injury Surveillance System (ISS) sample. Numbers do not always sum to totals because of missing division or season information.

Table 4. Percentage of Game and Practice Injuries by Major Body Part, Women's Lacrosse, 1988–1989 Through 2003–2004

Body Part	Games	Practices
Head/neck	21.9	12.0
Upper extremity	8.9	5.9
Trunk/back	6.1	12.0
Lower extremity	61.0	64.3
Other/system	2.2	5.9

A-Es, rate ratio = 1.4, 95% CI = 1.2, 1.6, $P < .01$; practices: 3.85 versus 2.87 injuries per 1000 A-Es, rate ratio = 1.3, 95% CI = 1.2, 1.5, $P < .01$). Division I injury rates were higher than those in Division II for practices (3.85 versus 2.84 injuries per 1000 A-Es, rate ratio = 1.4, 95% CI = 1.2, 1.6, $P < .01$) and were higher, but not significantly different, for games (8.56 versus 6.79 injuries per 1000 A-Es, rate ratio = 1.3, 95% CI = 1.0, 1.6, $P = .20$). Preseason practice injury rates were almost twice as high as regular-season practice rates (4.29 versus 2.47 per 1000 A-Es, rate ratio = 1.7, 95% CI = 1.6, 1.9, $P < .01$). Regular-season game injury rates were higher than postseason rates (7.32 versus 5.20 per 1000 A-Es, rate ratio = 1.4, 95% CI = 1.0, 1.9, $P = .03$).

Body Parts Injured Most Often and Specific Injuries

The frequency of injury to 5 general body parts (head/neck, upper extremity, trunk/back, lower extremity, and other/system) for games and practices with years and divisions combined is shown in Table 4. More than 60% of all game and practice injuries were to the lower extremity. Approximately 22% of all game injuries and 12% of all practice injuries involved the head and neck.

The most common body part and injury type combinations for games and practices are displayed in Table 5. All injuries that accounted for at least 1% of reported injuries over the 16-year sampling period were included. In games, ankle ligament sprains (22.6%), knee internal derangement (14.0%), concussions (9.8%), and upper leg muscle strains (7.2%) accounted for the majority of injuries. In practices, ankle ligament sprains accounted for the largest proportion of all reported injuries (15.5%), followed by upper leg muscle strains (11.7%) and knee internal derangements (6.1%). Participants had almost 5 times the risk of sustaining a concussion or a knee internal derangement during a game compared with during a practice (concussion: 0.70 versus 0.15 injuries per 1000 A-Es, rate ratio = 4.6, 95% CI = 3.5, 6.0; knee: 1.00 versus 0.20 injuries per 1000 A-Es, rate ratio = 4.9, 95% CI = 3.9, 6.2) and 3 times the risk of sustaining an ankle ligament sprain during a game compared with during a practice (1.62 versus 0.51 injuries per 1000 A-Es, rate ratio = 3.2, 95% CI = 2.7, 3.7).

Mechanism of Injury

The 3 primary injury mechanisms—player contact, other contact (eg, balls, sticks, ground), and no direct contact to the injured body part—in games and practices across divisions and years of surveillance are displayed in Figure 2. The greatest proportion of game injuries (44.3%) resulted from no direct contact. A total of 35.9% of game injuries were associated with other contact (primarily stick or ball) and 18.6% with player contact. The majority of practice injuries (62.0%) involved a no-contact mechanism.

Table 5. Most Common Game and Practice Injuries, Women's Lacrosse, 1988–1989 Through 2003–2004*

Body Part	Injury Type	Frequency	Percentage of Injuries	Injury Rate per 1000 Athlete-Exposures	95% Confidence Interval
Games					
Ankle	Ligament sprain	241	22.6	1.62	1.41, 1.82
Knee	Internal derangement	149	14.0	1.00	0.84, 1.16
Head	Concussion	105	9.8	0.70	0.57, 0.84
Upper leg	Muscle-tendon strain	77	7.2	0.52	0.40, 0.63
Nose	Fracture	27	2.5	0.18	0.11, 0.25
Pelvis, hip	Muscle-tendon strain	24	2.3	0.16	0.10, 0.23
Patella	Patella or patella tendon injury	22	2.1	0.15	0.09, 0.21
Upper leg	Contusion	21	2.0	0.14	0.08, 0.20
Lower back	Muscle-tendon strain	15	1.4	0.10	0.05, 0.15
Foot	Ligament sprain	14	1.3	0.09	0.05, 0.14
Head	Laceration	14	1.3	0.09	0.05, 0.14
Unspecified†	Unspecified	14	1.3	0.09	0.05, 0.14
Eye(s)	Contusion	13	1.2	0.09	0.04, 0.13
Lower leg	Muscle-tendon strain	13	1.2	0.09	0.04, 0.14
Practices					
Ankle	Ligament sprain	361	15.5	0.51	0.46, 0.56
Upper leg	Muscle-tendon strain	273	11.7	0.39	0.34, 0.43
Knee	Internal derangement	143	6.1	0.20	0.17, 0.24
Pelvis, hip	Muscle-tendon strain	116	5.0	0.16	0.13, 0.19
Unspecified†	Unspecified	113	4.9	0.16	0.13, 0.19
Head	Concussion	108	4.6	0.15	0.12, 0.18
Lower leg	Stress fracture	102	4.4	0.14	0.12, 0.17
Lower leg	Muscle-tendon strain	70	3.0	0.10	0.08, 0.12
Patella	Patella or patella tendon injury	62	2.7	0.09	0.07, 0.11
Lower back	Muscle-tendon strain	59	2.5	0.08	0.06, 0.11
Nose	Fracture	52	2.2	0.07	0.05, 0.09
Lower leg	Inflammation	50	2.1	0.07	0.05, 0.09
Foot	Ligament sprain	33	1.4	0.05	0.03, 0.06
Eye(s)	Contusion	31	1.3	0.04	0.03, 0.06
Foot	Stress fracture	31	1.3	0.04	0.03, 0.06
Knee	Tendinitis	29	1.2	0.04	0.03, 0.06
Lower leg	Tendinitis	29	1.2	0.04	0.03, 0.06
Heel/Achilles tendon	Tendinitis	25	1.1	0.04	0.02, 0.05

*Only injuries that accounted for at least 1% of all injuries are included.
†"Unspecified" indicates injuries that could not be grouped into existing categories but that were believed to constitute reportable injuries.

Severe Injuries: 10+ Days of Activity Time Loss

The top injuries that resulted in at least 10 consecutive days of restricted or total loss of participation and their primary injury mechanisms are presented in Table 6. Time loss of 10+ days was, for this analysis, considered a measure of severe injury. A total of 22% of game and 24% of practice injuries were severe enough to restrict participation for at least 10 days. In games, knee internal derangements accounted for almost half of all severe injuries, followed by ankle ligament sprains. Head injuries represented 7% of the severe game injuries (data not shown). In practices, lower leg stress fractures, knee internal derangements, and ankle ligament sprains were the primary severe injuries.

Game Injuries

Game injury mechanisms and player activity are shown in greater detail in Figures 3 and 4. The primary injury mechanism involved no direct contact (40.5%), followed by contact from a player (18.6%) and contact from a stick (17.5%). The most common activities at the time of injury during a game were ball handling (39.5%) and loose ball situations (30.2%), and the most common injury scenarios were no contact while ball handling (16.4%) and contact from a stick while ball handling (10.5%). Contact from a stick and contact from a ball accounted for 5.6% and 5.2% of injuries sustained during shooting activities, respectively. In terms of field location, one third of the injuries (32.5%) from 1996–1997 through 2003–2004 (this variable was not collected over the entire study period) occurred within the 8-m arc, and an additional 12.8% of game injuries occurred in the goal area (Figure 5).

Above-the-neck injuries accounted for 22% of all game injuries. The frequency of above-the-neck injuries in games by specific body part and the top 2 associated mechanisms of injury are displayed in Table 7. Of the 226 above-the-neck injuries sustained in games, the most common anatomic sites were the head (n = 129, 56.8%), nose (n = 40, 17.6%), and eye (n = 30, 13.2%). Contact from a stick accounted for the majority (56%) of mechanisms resulting in above-the-neck injuries in games, whereas contact from the ball accounted for 20% of these injuries.

COMMENTARY

Women's lacrosse is a rapidly evolving sport. The dramatic increase in lacrosse participation (evidenced by the 119% in-

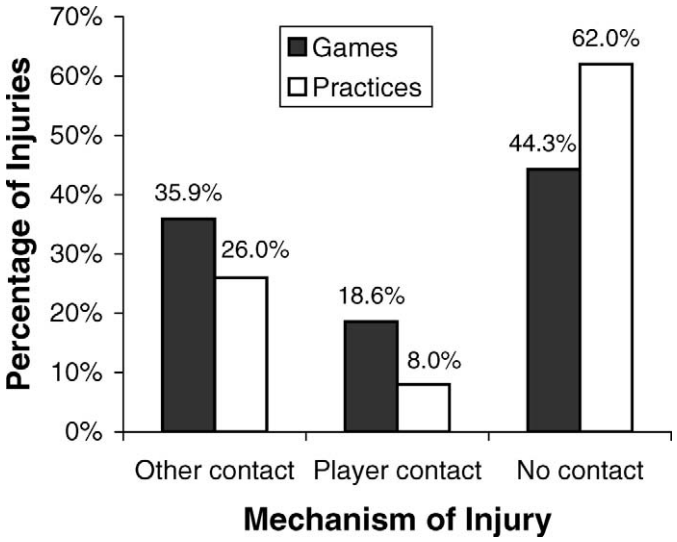


Figure 2. Game and practice injury mechanisms, all injuries, women's lacrosse, 1988–1989 through 2003–2004 (n = 1066 game injuries and 2326 practice injuries). "Other contact" refers to contact from items such as sticks, balls, or the ground. Injury mechanism was unavailable for 1% of game injuries and 5% of practice injuries.

crease in women's varsity teams during the 16-year time span from 1988–1989 through 2003–2004) indicates that lacrosse is becoming the sport of choice among a larger number of collegiate-level women athletes. Factors such as increased participation levels, greater athleticism among players, the use of more sophisticated equipment (eg, sticks made of strong, lightweight composite materials rather than wood), and changes in tactics are most likely associated with the increase in game injury rates seen in this study.[3] Further efforts are needed to better understand injury mechanisms, to improve conditioning, and to prevent injuries, especially in competitive game situations.

The vast majority of women's lacrosse injuries were minor strains, sprains, and contusions. However, major injuries do occur, and priority issues for the women's game appear to be ligament injuries of the ankle and knee as well as injuries to the head, face, and eye. In both games and practices, noncontact incidents accounted for the greatest proportion of injuries. These findings are consistent with previously published data on female collegiate players and girls' high school players,[5] in whom ankles and knees were the most commonly injured body parts. These injuries reflect the high-speed, quick change of direction inherent to the sport. The top 3 game and practice injuries were identical for both male and female lacrosse players, despite differences in levels of contact permitted and protective equipment worn.[6]

Above-the-neck injuries accounted for more than 20% of all game injuries and 7% of serious game injuries. These included concussions as well as fractures, lacerations, and contusions. In particular, the rate of concussion was 5 times higher in games than in practices. Contact from a stick was responsible for more than half of the head injuries, whereas the majority of eye injuries were caused by contact from either a stick or ball. These data are similar to findings from studies in female collegiate and high school lacrosse players, in whom the most

Table 6. Most Common Game and Practice Injuries Resulting in 10+ Days of Activity Time Loss, Women's Lacrosse, 1988–1989 Through 2003–2004

Body Part	Injury Type	Frequency	Percentage of Severe Injuries	Most Common Injury Mechanism
Games (21.9% of all injuries required 10+ days of time loss)				
Knee	Internal derangement	111	47.6	Noncontact
Ankle	Ligament sprain	33	14.2	Noncontact, player contact
Other		89	38.2	
Total		233		
Practices (23.9% of all injuries required 10+ days of time loss)				
Lower leg	Stress fracture	88	15.8	Noncontact
Knee	Internal derangement	84	15.1	Noncontact
Ankle	Ligament sprain	59	10.6	Noncontact
Other		325	58.5	
Total		556		

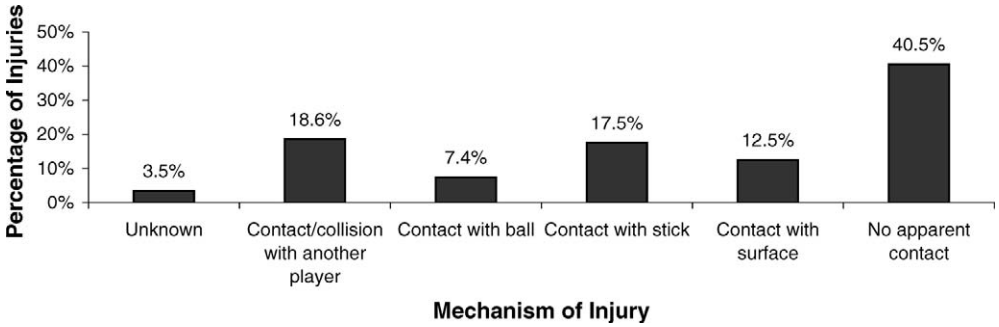


Figure 3. Sport-specific game injury mechanisms, women's lacrosse, 1988–1989 through 2003–2004 (n = 1066).

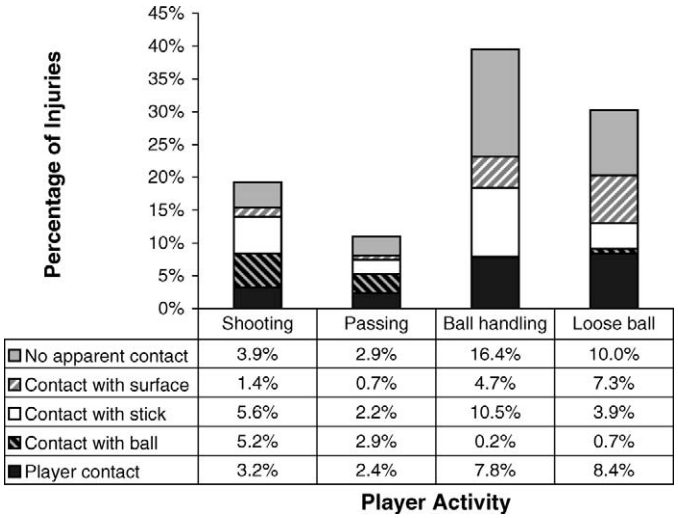


Figure 4. Game player activity at time of game injury, 1988–1989 through 2003–2004 (n = 594, which does not include 472 other injuries recorded as "other" or with missing data).

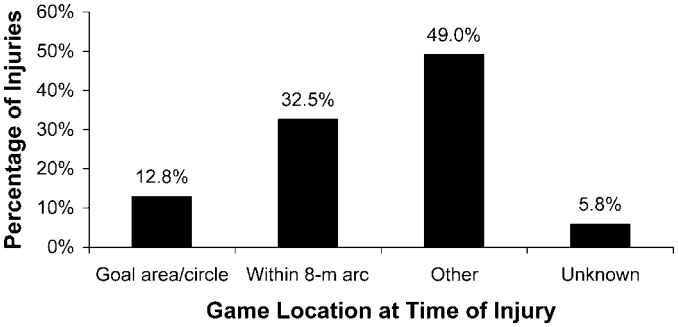


Figure 5. Location at time of game injury, women's lacrosse, 1996–1997 through 2003–2004 (n = 788). The goal area/circle is exclusive of the area within the 8-m arc on a regulation-size field.

common mechanisms of trauma to the head and face were being hit by a stick or a ball.[4,7–9]

We found that the game injury mechanisms of player contact and contact from a stick accounted for more than one third of all game injuries. For a sport in which contact is considered only an incidental event, these mechanisms indicate that the term ''incidental'' may be a misnomer, giving players a false sense of the common mechanisms of injury.

Dramatic differences were noted in injury rates by setting (games versus practices, division levels, and seasons). Game injury rates were twice as high as those reported during practices. Game and practice injury rates were highest in Division I teams. These findings indicate that competition intensity may be directly related to injury risk. Also, the elevated preseason injury rates and large proportion of noncontact lower extremity injuries may be associated with the lower conditioning levels clinicians often observe at the beginning of the season.

The data presented reflect the injuries we see in clinical practice for woman's lacrosse. These results support the anecdotal impression that with increased athleticism and a more physically developing women's game, injuries of a contact nature (from a stick, ball, or another player) are becoming a greater concern. Noncontact sprain and strain injuries to the lower extremity are also frequent in women lacrosse players. Given the high incidence and time loss associated with such injuries, they represent one of several focal areas for injury prevention efforts.

From the clinical standpoint, it will be interesting to see if lacrosse-specific training programs targeting proprioception and core sport mechanics will decrease rates of ankle and knee ligament injuries, as they appear to have done in soccer and some other field sports. Field trials of interventions based on proprioception and balance development have demonstrated significant reductions of anterior cruciate ligament injuries and ankle sprains in other women's sports.[10–16] However, results from 2 recent trials on plyometric-based exercise programs designed to reduce rates of anterior cruciate ligament injuries indicate that this type of intervention was not effective in youth-level and high school–level female soccer, basketball, and volleyball players.[17,18] Although many of the skills re-

Table 7. Above-the-Neck Injuries in Games by Top Injury Mechanisms, Women's Lacrosse, 1988–1989 Through 2003–2004*

Body Part	Injury Frequency	Most Common Injury Mechanism(s)	Percentage of Injuries for Each Body Part
Head (not elsewhere classified in this table)	129	Stick	54.0
		Player contact	21.0
Eye	30	Stick	43.0
		Ball	47.0
Nose	40	Stick	63.0
		Ball	23.0
Face	12	Stick	83.0
		Ball	17.0
Chin	2	Stick	50.0
		Ball	50.0
Jaw	5	Ball	29.0
		Player contact	29.0
Mouth	3	Stick	67.0
		Ball	33.0
Teeth	5	Stick	80.0
Total	226	Stick	56.0
		Ball	20.0

quired for these sports (eg, quick changes of direction, pivoting) are similar to those required for lacrosse, the effectiveness of plyometrics programs has yet to be demonstrated in a population of lacrosse players.

The elevated rate of preseason and noncontact injuries indicates the need to maintain conditioning throughout the off-season and to implement progressive conditioning as organized preseason practices begin. However, a thorough assessment of conditioning status during the off-season and preseason is needed to evaluate the level of change from mid-season form.

Head and facial injuries resulting from stick-to-body contact represent an opportunity for intervention. Although these data represent injury risk before the use of protective eyewear was mandated in 2004,[19] they illustrate important areas of concern. Most game head and facial injuries associated with stick contact indicate the limitation of the ''bubble rule'' in protecting players from head and facial injuries. (The ''bubble rule'' prohibits a player from placing her stick within 7 in [17.78 cm] of the opponent's head.[20]) Even if the vast majority of injuries are unintentional, the frequency of above-the-neck injuries indicates that relying on players to self-monitor the location (and use) of their sticks relative to the other players' heads and faces to prevent injury is insufficient. In addition, the path of the ball, either directly or when deflected, does not recognize an imaginary bubble. Our findings indicate that relying on players' behavior, rather than protective equipment, is not effective in safeguarding players from potentially serious or disfiguring head and facial injuries.

These findings indicate that almost half of the game injuries occur within the 8-m arc and goal area, with one third of injuries within the 8-m arc. The disproportionate relationship between the proportion of overall injuries and this small area in front of the goal indicates the need to reassess the effectiveness of rules within this shooting space (obstruction of free space to goal) intended to protect players.

To reduce the lower extremity injuries that compose the greatest injury burden in women's lacrosse, future researchers should evaluate proprioception, plyometrics, and balance training interventions specifically for women lacrosse players. Another area of great interest to the clinician is the effect of the mandatory protective eyewear in preventing injury to the eye, orbit, and nasal area. In addition to assessing changes in eye injury rates, investigators should assess unintended consequences of the mandate. These include the potential for increased injuries to other areas of the face or more aggressive play associated with the recent rule change. In a survey administered to collegiate and postcollegiate female lacrosse players in 2002, more than half of the players thought that introducing protective eyewear would result in increased illegal contact.[8] These evaluations will address such concerns among the women's lacrosse community that introducing any protective equipment (such as eyewear or helmets) may result in more aggressive play and, ultimately, additional risk of injury and changes to the nature of the game. Similar concern existed when helmets were introduced for ice hockey players in the 1970s, although later studies failed to demonstrate evidence of either greater risk of injuries or increased aggression in the game.[21,22]

A recently developed research method with potential applicability to women's lacrosse is video incident analysis. Such an approach has been used in other sports to identify specific play situations in which common injuries and mechanisms occur.[23–25] A better understanding of play situations will enable researchers and sports officials to devise the most appropriate combination of interventions (rule changes, conditioning techniques, and protective equipment) to improve the safety of collegiate women's lacrosse.[26]

In conclusion, women's lacrosse is a rapidly growing collegiate sport in which game injury rates increased at a moderate rate over the 16-year study period. The combination of unique physical requirements (such as running, throwing, and quick changes of direction) with potentially harmful equipment (a hard ball and long sticks) and physical play generates hazards, primarily resulting in lower extremity sprains and strains and contact injuries about the head and face. Several opportunities for injury prevention deserve consideration. Among them, more sophisticated interventions and research methods should be considered to assess whether protective equipment would reduce head, facial, and eye injuries and, ultimately, improve safety without altering the nature and aggression of the game.

DISCLAIMER

The conclusions in the Commentary section of this article are those of the Commentary authors and do not necessarily represent the views of the National Collegiate Athletic Association.

REFERENCES

1. National Collegiate Athletic Association. *1981-82–2004-05 NCAA Sports Sponsorship and Participation Rates Report.* Indianapolis, IN: National Collegiate Athletic Association; 2006.
2. Dick R, Agel J, Marshall SW. National Collegiate Athletic Association Injury Surveillance System commentaries: introduction and methods. *J Athl Train.* 2007;42:173–182.
3. Livingston LA. Recent crosse designs increase ball velocity: implications for injury in women's lacrosse. *J Sci Med Sport.* 2006;9:299–303.
4. Matz SO, Nibbelink G. Injuries in intercollegiate women's lacrosse. *Am J Sports Med.* 2004;32:608–611.
5. Hinton RY, Lincoln AE, Almquist JL, Douoguih WA, Sharma KM. Epidemiology of lacrosse injuries in high school–aged girls and boys: a 3-year prospective study. *Am J Sports Med.* 2005;33:1305–1314.
6. Agel J, Romani WA, Dick R, Case JG, Marshall SM. Descriptive epidemiology of collegiate men's lacrosse injuries: National Collegiate Athletic Association Injury Surveillance System, 1988–1989 through 2003–2004. *J Athl Train.* 2007;42:255–261.
7. Goldenberg MS, Hossler PH. Head and facial injuries in interscholastic women's lacrosse. *J Athl Train.* 1995;30:37–41.
8. Waicus KM, Smith BW. Eye injuries in women's lacrosse players. *Clin J Sport Med.* 2002;12:24–29.
9. Lincoln AE, Hinton RY, Almquist JL, Lager SL, Dick RW. Head, face and eye injuries in scholastic and collegiate lacrosse: a 4-year prospective study. *Am J Sports Med.* 2007;35:207–215.
10. Bahr R, Lian O, Bahr IA. A twofold reduction in the incidence of acute ankle sprains in volleyball after the introduction of an injury prevention program: a prospective cohort study. *Scand J Med Sci Sports.* 1997;7: 172–177.
11. Caraffa A, Cerulli G, Projetti M, Aisa G, Rizzo A. Prevention of anterior cruciate ligament injuries in soccer: a prospective controlled study of proprioceptive training. *Knee Surg Sports Traumatol Arthrosc.* 1996;4: 19–21.
12. Myklebust G, Engebretsen L, Braekken IH, Skjolberg A, Olsen OE, Bahr R. Prevention of anterior cruciate ligament injuries in female team handball players: a prospective intervention study over three seasons. *Clin J Sport Med.* 1996;13:71–78.
13. Thacker SB, Stroup DF, Branche CM, Gilchrist J, Goodman RA, Weitman

EA. The prevention of ankle sprains in sports: a systematic review of the literature. *Am J Sports Med.* 1999;27:753–760.
14. Verhagen E, van der Beek A, Twisk J, Bouter L, Bahr R, van Mechelen W. The effect of a proprioceptive balance board training program for the prevention of ankle sprains: a prospective controlled trial. *Am J Sports Med.* 2004;32:1385–1393.
15. Wedderkopp N, Kaltoft M, Lundgaard B, Rosendahl M, Froberg K. Prevention of injuries in young female players in European team handball: a prospective intervention study. *Scand J Med Sci Sports.* 1999;9:41–47.
16. Wester JU, Jespersen SM, Nielsen KD, Neumann L. Wobble board training after partial sprains of the lateral ligaments of the ankle: a prospective randomized study. *J Orthop Sports Phys Ther.* 1996;23:332–336.
17. Grandstrand SL, Pfeiffer RP, Sabick MB, DeBeliso M, Shea KG. The effects of a commercially available warm-up program on landing mechanics in female youth soccer players. *J Strength Cond Res.* 2006;20: 331–335.
18. Pfeiffer RP, Shea KG, Roberts D, Grandstrand S, Bond L. Lack of effect of a knee ligament injury prevention program on the incidence of noncontact anterior cruciate ligament injury. *J Bone Joint Surg Am.* 2006; 88:1769–1774.
19. US Lacrosse. 2006 Women's rules, major fouls, rule 18 A-1. 1-1-0006. Available at: http://www.usalacrosse.org/the_sport/womens_rules.phtml. Accessed January 19, 2007.
20. US Lacrosse. Position statement on eye protection in women's lacrosse. Available at: http://www.uslacrosse.org/safety/eyeprotection.phtml. Accessed January 19, 2007.
21. Benson BW, Mohtadi NG, Rose MS, Meeuwisse WH. Head and neck injuries among ice hockey players wearing full face shields vs half face shields. *JAMA.* 1999;282:2328–2332.
22. Stoner LJ, Keating M. Hockey equipment: safety or an illusion? In: Castaldi CR, Bishop PJ, Hoerner EF, eds. *Safety in Ice Hockey.* Vol 2. Philadelphia, PA: American Society for Testing and Materials; 1993:183–191.
23. Andersen TE, Arnason A, Engebretsen L, Bahr R. Mechanisms of head injuries in elite football. *Br J Sports Med.* 2004;38:690–696.
24. Andersen TE, Larsen O, Tenga A, Engebretsen L, Bahr R. Video analysis of injuries and incidents in Norwegian professional football. *Br J Sports Med.* 2004;38:626–631.
25. Andersen TE, Tenga A, Engebretsen L, et al. Football incident analysis: a new video based method to describe injury mechanisms in professional football. *Br J Sports Med.* 2003;37:226–232.
26. Biasca N, Wirth S, Tegner Y. The avoidability of head and neck injuries in ice hockey: an historical review. *Br J Sports Med.* 2002;36:410–427.

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