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# Descriptive Epidemiology of Collegiate Men'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 (NCAA) injury surveillance data for men's lacrosse and identify potential areas for injury prevention initiatives.

***Background:*** During the sample period, the number of sponsoring institutions and the number of participants in men's college lacrosse grew significantly. Overall, an average of 18% of NCAA institutions participated in the annual NCAA Injury Surveillance System data collection for this sport.

***Main Results:*** Over the sample period, athletes were almost 4 times more likely to sustain injuries in games than in practices (12.58 versus 3.24 injuries per 1000 athlete-exposures [A-Es], rate ratio = 3.9, 95% confidence interval = 3.7, 4.1). Approximately half of all game (48.1%) and practice (58.7%) injuries were to the lower extremity, followed by the upper extremity (26.2% in games, 16.9% in practices), and the head and neck (11.7% in games, 6.2% in practices). In games and practices, the most common injuries were ankle ligament sprains (11.3% and 16.4%, respectively). The disparity among preseason, regular-season, and postseason injuries may be due to athlete acclimatization to the rigors of the sport throughout the season. Changes in helmet design may account for the rise in the concussion rate since the 1995–1996 season.

***Recommendations:*** We recommend research into the mechanism of head injuries and the implications of design changes to protective helmets, as well as further investigation of the best designs for shoulder and chest protection.

***Key Words:*** athletic injuries, injury prevention, lower extremity injuries, ankle sprains, concussions, shoulder injuries

The National Collegiate Athletic Association (NCAA) conducted its first men's lacrosse championship in 1971. In the 1988–1989 academic year, 150 schools were sponsoring varsity men's lacrosse teams, with a total of 4805 participants. By the 2003–2004 year, the number of varsity teams had increased 41% to 211, involving 7100 participants.[1] Significant participation growth during this time has been apparent in all 3 divisions, particularly Divisions II and III.

## SAMPLING AND METHODS

Over the 16-year period from academic years 1988–1989 through 2003–2004, an average of 18% of schools sponsoring varsity men'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 numbers of games, practices, and athletes participating for each NCAA division, condensed over the study period, are shown in Table 2. Division I annually averaged 9 more practices than Divisions II or III, although the average number of games played across the divisions was similar. Division I averaged 9 more participants in practice than Division II and 5 more than Division III. The average number of game participants was similar across divisions.

### Injury Rate by Activity, Division, and Season

Game and practice injury rates over time combined across divisions with 95% confidence intervals (CIs) are displayed in Figure 1. Over the 16 years of the study, the rate of injury in a game compared with the practice rate was almost 4 times higher (12.58 versus 3.24 injuries per 1000 athlete-exposures [A-Es], rate ratio = 3.9, 95% CI = 3.7, 4.1). Game and practice injury rates did not show significant time trends over the sample period.

The total number of games and practices and associated injury rates collapsed over years by division and season (preseason, in season, and postseason) are presented in Table 3. (The fall season is not included in the ISS data.) Over the 16-year period, 1921 injuries from more than 6800 games and 2924 injuries from more than 29 000 practices were reported. Game and practice injury rates did not differ across divisions but did differ within season. Preseason practice injury rates were more than 2 times higher than regular-season practice

Table 1. School Participation Frequency (in Total Numbers) by Year and National Collegiate Athletic Association (NCAA) Division, Men'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 | 9 | 49 | 4 | 19 | 12 | 82 | 25 | 150 | 16.7 |
| 1989–1990 | 6 | 51 | 3 | 18 | 14 | 83 | 23 | 152 | 15.1 |
| 1990–1991 | 14 | 51 | 4 | 20 | 19 | 86 | 37 | 158 | 23.4 |
| 1991–1992 | 12 | 50 | 6 | 21 | 17 | 89 | 35 | 160 | 21.9 |
| 1992–1993 | 12 | 53 | 4 | 24 | 17 | 91 | 33 | 168 | 19.6 |
| 1993–1994 | 15 | 51 | 4 | 26 | 18 | 93 | 37 | 170 | 21.8 |
| 1994–1995 | 12 | 52 | 2 | 27 | 15 | 93 | 29 | 172 | 16.9 |
| 1995–1996 | 12 | 53 | 4 | 29 | 18 | 95 | 34 | 177 | 19.2 |
| 1996–1997 | 12 | 54 | 6 | 29 | 17 | 100 | 35 | 183 | 19.1 |
| 1997–1998 | 13 | 51 | 8 | 30 | 20 | 105 | 41 | 186 | 22.0 |
| 1998–1999 | 5 | 52 | 4 | 31 | 21 | 114 | 30 | 197 | 15.2 |
| 1999–2000 | 11 | 55 | 4 | 30 | 26 | 118 | 41 | 203 | 20.2 |
| 2000–2001 | 10 | 55 | 1 | 30 | 22 | 123 | 33 | 208 | 15.9 |
| 2001–2002 | 6 | 55 | 3 | 29 | 26 | 127 | 35 | 211 | 16.6 |
| 2002–2003 | 6 | 54 | 1 | 30 | 19 | 130 | 26 | 214 | 12.1 |
| 2003–2004 | 7 | 54 | 2 | 29 | 18 | 128 | 27 | 211 | 12.8 |
| Average | 10 | 53 | 4 | 26 | 19 | 104 | 33 | 183 | 18.0 |

*"Participating" refers to schools providing 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, Men's Lacrosse, 1988–1989 Through 2003–2004

| Division | Games | Athletes per Game | Practices | Athletes per Practice |
|---|---|---|---|---|
| I | 13 | 24 | 66 | 34 |
| II | 13 | 20 | 57 | 25 |
| III | 14 | 22 | 57 | 29 |

rates (4.89 versus 1.99 injuries per 1000 A-Es, rate ratio = 2.5, 95% CI = 2.3, 2.7, $P = .01$). In-season game injury rates were almost twice as high as those in the postseason (12.60 versus 7.54 injuries per 1000 A-Es, rate ratio = 1.7, 95% CI = 1.3, 2.2, $P < .01$).

## 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. A total of 48.1% of all game and 58.7% of all practice injuries were to the lower extremity. The upper extremity accounted for another 26.2% of game injuries and 16.9% of practice injuries, whereas 11.7% of game and 6.2% of practice injuries involved the head and neck.

The most common body part and injury type combinations for games and practices, with years and divisions combined, are displayed in Table 5. All injuries that accounted for at least 1% of reported injuries over the 16-year sampling period are included. In games, ankle ligament sprains (11.3%), knee internal derangements (9.1%), concussions (8.6%), and upper leg contusions (8.0%) and muscle strains (7.5%) accounted for most of the injuries. In practices, ankle ligament sprains accounted for 16.4% of all reported injuries. Upper leg muscle-tendon strains (11.4%) and knee internal derangements (7.1%) were also common injury categories in practices. Concussions accounted for 3.6% of practice injuries. A participant was 9 times more likely to sustain a concussion in a game than in a practice (1.08 versus 0.12 injuries per 1000 A-Es, rate ratio = 9.0, 95% CI = 7.1, 11.5), 5 times more likely to sustain a knee internal derangement in a game than in a practice (1.14 versus 0.23 injuries per 1000 A-Es, rate ratio = 5.0, 95% CI = 4.1, 6.1), and almost 3 times more likely to sustain an ankle ligament sprain in a game than in a practice (1.43 versus 0.53 injuries per 1000 A-Es, rate ratio = 2.7, 95% CI = 2.3, 3.2).

## Mechanism of Injury

The 3 primary injury mechanisms—player contact, other contact (eg, contact with balls, sticks, or the ground), and no contact—in games and practices, with division and years combined, are presented in Figure 2. Most game injuries (45.9%) resulted from player contact, whereas the rest were equally distributed between other contact (primarily contact with the stick) and no direct contact to the injured body part. The majority of practice injuries (50.0%) involved no direct contact.

## 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, combined across divisions and years, are shown in Table 6. For this analysis, time loss of 10+ days was considered a measure of severe injury. A total of 21.0% of both game and practice injuries restricted participation for at least 10 days. In games, knee internal derangements accounted for 27.3% of all severe injuries, followed by acromioclavicular joint injuries (7.3%), ankle ligament sprains (7.1%), and upper leg muscle strains (5.6%). Concussions accounted for 3% of severe game injuries (data not shown). In practices, these same areas, except for acromioclavicular joint injuries, accounted for most of the severe injuries.

## Game Injuries

Game injury mechanisms are displayed in more detail in Figure 3. A total of 45.9% of game injuries were associated

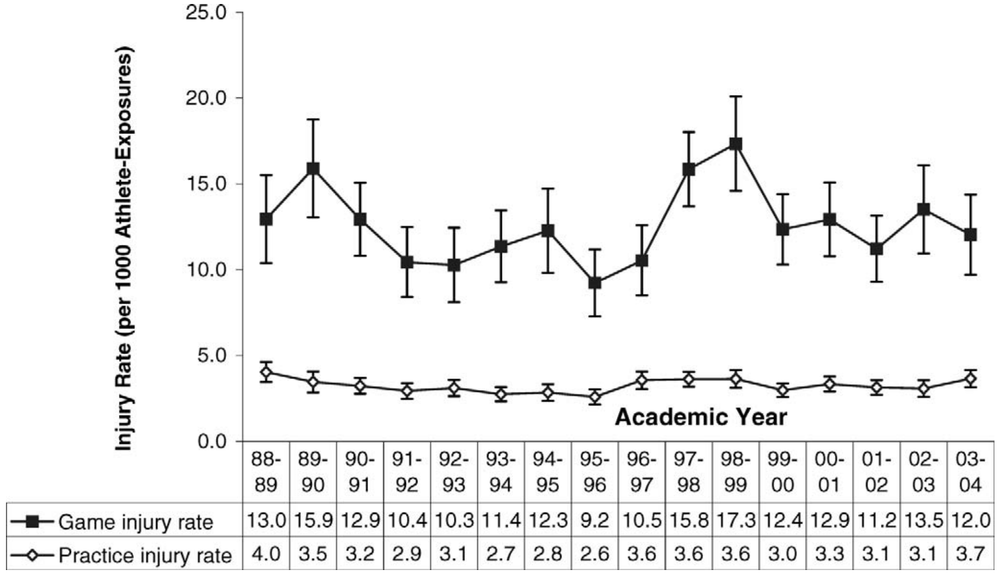


**Figure 1. Injury rates and 95% confidence intervals per 1000 athlete-exposures by games, practices, and academic years, men's lacrosse, 1988–1989 through 2003–2004 (n = 1921 game injuries and 2924 practice injuries). Game time trend $P = .80$. Average annual change in game injury rate = −0.3%, 95% confidence interval = −1.7, 2.3. Practice time trend $P = .90$. Average annual change in practice injury rate = −0.1%, 95% confidence interval = −1.2, 1.4.**

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

| | Total No. of Games Reported | Game Injury Rate per 1000 Athlete-Exposures | 95% Confidence Interval | Total No. of Practices Reported | Practice Injury Rate per 1000 Athlete-Exposures | 95% Confidence Interval |
|---|---|---|---|---|---|---|
| Division I | | | | | | |
| Preseason | 105 | 12.94 | 8.52, 17.35 | 4057 | 5.14 | 4.77, 5.51 |
| In season | 1896 | 13.35 | 12.28, 14.42 | 5999 | 2.15 | 1.95, 2.35 |
| Postseason | 69 | 5.86 | 2.23, 9.50 | 355 | 1.72 | 1.02, 2.42 |
| Total Division I | 2070 | 13.07 | 12.06, 14.08 | 10 411 | 3.36 | 3.17, 3.55 |
| Division II | | | | | | |
| Preseason | 18 | 17.11 | 4.44, 29.79 | 1319 | 4.40 | 3.68, 5.11 |
| In season | 665 | 10.96 | 9.17, 12.74 | 1699 | 1.72 | 1.31, 2.12 |
| Postseason | 29 | 5.34 | 0.00, 11.38 | 65 | 2.01 | 0.00, 4.28 |
| Total Division II | 712 | 14.20 | 12.2, 16.10 | 3083 | 3.40 | 3.00, 3.90 |
| Division III | | | | | | |
| Preseason | 140 | 21.61 | 16.55, 26.67 | 6939 | 4.79 | 4.49, 5.09 |
| In season | 3685 | 12.46 | 11.69, 13.23 | 8278 | 1.89 | 1.72, 2.07 |
| Postseason | 195 | 8.44 | 5.76, 11.13 | 508 | 1.38 | 0.83, 1.93 |
| Total Division III | 4020 | 12.57 | 11.84, 13.31 | 15 725 | 3.19 | 3.03, 3.35 |
| All Divisions | | | | | | |
| Preseason | 263 | 17.74 | 14.43, 21.06 | 12 315 | 4.89 | 4.67, 5.11 |
| In season | 6246 | 12.60 | 12.01, 13.19 | 15 976 | 1.99 | 1.86, 2.11 |
| Postseason | 293 | 7.54 | 5.47, 9.60 | 928 | 1.55 | 1.12, 1.98 |
| Total | 6830 | 12.58 | 12.01, 13.14 | 29 299 | 3.24 | 3.12, 3.35 |

*Wald $\chi^2$ statistics from negative binomial model: game injury rates did not differ among divisions ($P = .16$) but did differ within season ($P < .01$); practice injury rates did not differ among divisions ($P = .06$) but did differ within season ($P < .01$). Postseason sample sizes were much smaller (and had 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 sample. Numbers do not always sum to totals because of missing division or season information.

with player contact, and 12.9% were associated with stick contact. Contact with the ball was associated with only 3% of all game injuries.

Player location at time of game injury is presented in Figure 4. From 1996–1997 through 2003–2004 (this variable was not collected over the entire study period), approximately one quarter of all game injuries occurred near the goal area, and another one quarter occurred within the 25-yd line.

The breakdown of game concussions by mechanism is shown in Figure 5. Most concussions (78.5%) were associated

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

| Body Part | Games | Practices |
|---|---|---|
| Head/neck | 11.7 | 6.2 |
| Upper extremity | 26.2 | 16.9 |
| Trunk/back | 11.9 | 14.4 |
| Lower extremity | 48.1 | 58.7 |
| Other/system | 2.2 | 3.8 |

with player contact, with stick contact accounting for another 10.4%.

During the 1996–1997 season, a new helmet design was introduced and widely adopted (see "Commentary" section). We therefore compared the concussion rate in the postintroduction period (1996–1997 to 2003–2004) to the rate in the preintroduction period (1988–1989 to 1995–1996). For both practices and games, concussion rates were higher in the postintroduction period than in the preintroduction period. In practices, the rate increased from 0.04 to 0.18 concussions per 1000 A-Es, an increase of 0.14 (95% CI = 0.09, 0.19) concussions per 1000 A-Es ($P < .01$). In games, the increase was from 0.63 to 1.47 concussions per 1000 A-Es, an increase of 0.84 (95% CI = 0.52, 1.16) concussions per 1000 A-Es ($P < .01$). We caution that this increase may be due, in part, to improved detection of concussions (see "Commentary").

## COMMENTARY

Steady growth has been seen in men's collegiate lacrosse across all 3 NCAA divisions. Although the number of teams

Table 5. Most Common Game and Practice Injuries, Men'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 | 218 | 11.3 | 1.43 | 1.24, 1.62 |
| Knee | Internal derangement | 174 | 9.1 | 1.14 | 0.97, 1.31 |
| Head | Concussion | 165 | 8.6 | 1.08 | 0.92, 1.25 |
| Upper leg | Contusion | 153 | 8.0 | 1.00 | 0.84, 1.16 |
| Upper leg | Muscle-tendon strain | 144 | 7.5 | 0.94 | 0.79, 1.10 |
| Shoulder | Acromioclavicular joint injury | 98 | 5.1 | 0.64 | 0.51, 0.77 |
| Shoulder | Ligament sprain | 79 | 4.1 | 0.52 | 0.40, 0.63 |
| Pelvis, hip | Muscle-tendon strain | 63 | 3.3 | 0.41 | 0.31, 0.51 |
| Ribs | Contusion | 36 | 1.9 | 0.24 | 0.16, 0.31 |
| Shoulder | Contusion | 35 | 1.8 | 0.23 | 0.15, 0.31 |
| Lower leg | Contusion | 32 | 1.7 | 0.21 | 0.14, 0.28 |
| Unspecified† | Unspecified | 30 | 1.6 | 0.20 | 0.13, 0.27 |
| Knee | Contusion | 26 | 1.4 | 0.17 | 0.10, 0.24 |
| Shoulder | Muscle-tendon strain | 26 | 1.4 | 0.17 | 0.10, 0.24 |
| Patella | Patella or patella tendon injury | 24 | 1.2 | 0.16 | 0.09, 0.22 |
| Pelvis, hip | Contusion | 23 | 1.2 | 0.15 | 0.09, 0.21 |
| Thumb | Fracture | 23 | 1.2 | 0.15 | 0.09, 0.21 |
| Lower back | Muscle-tendon strain | 22 | 1.1 | 0.14 | 0.08, 0.20 |
| Neck | Muscle-tendon strain | 19 | 1.0 | 0.12 | 0.07, 0.18 |
| Practices | | | | | |
| Ankle | Ligament sprain | 480 | 16.4 | 0.53 | 0.48, 0.58 |
| Upper leg | Muscle-tendon strain | 333 | 11.4 | 0.37 | 0.33, 0.41 |
| Knee | Internal derangement | 207 | 7.1 | 0.23 | 0.20, 0.26 |
| Pelvis, hip | Muscle-tendon strain | 165 | 5.6 | 0.18 | 0.15, 0.21 |
| Head | Concussion | 106 | 3.6 | 0.12 | 0.10, 0.14 |
| Unspecified† | Unspecified | 93 | 3.2 | 0.10 | 0.08, 0.12 |
| Lower back | Muscle-tendon strain | 90 | 3.1 | 0.10 | 0.08, 0.12 |
| Upper leg | Contusion | 88 | 3.0 | 0.10 | 0.08, 0.12 |
| Patella | Patella or patella tendon injury | 59 | 2.0 | 0.07 | 0.05, 0.08 |
| Shoulder | Acromioclavicular joint injury | 56 | 1.9 | 0.06 | 0.05, 0.08 |
| Shoulder | Ligament sprain | 52 | 1.8 | 0.06 | 0.04, 0.07 |
| Lower leg | Muscle-tendon strain | 47 | 1.6 | 0.05 | 0.04, 0.07 |
| Lower leg | Contusion | 46 | 1.6 | 0.05 | 0.04, 0.07 |
| Thumb | Fracture | 45 | 1.5 | 0.05 | 0.04, 0.06 |
| Shoulder | Subluxation | 40 | 1.4 | 0.04 | 0.03, 0.06 |
| Knee | Contusion | 35 | 1.2 | 0.04 | 0.03, 0.05 |
| Shoulder | Contusion | 35 | 1.2 | 0.04 | 0.03, 0.05 |
| Knee | Tendonitis | 31 | 1.1 | 0.03 | 0.02, 0.05 |
| Foot | Ligament sprain | 30 | 1.0 | 0.03 | 0.02, 0.05 |
| Shoulder | Muscle-tendon strain | 30 | 1.0 | 0.03 | 0.02, 0.05 |
| Knee | Muscle-tendon strain | 28 | 1.0 | 0.03 | 0.02, 0.04 |

*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.

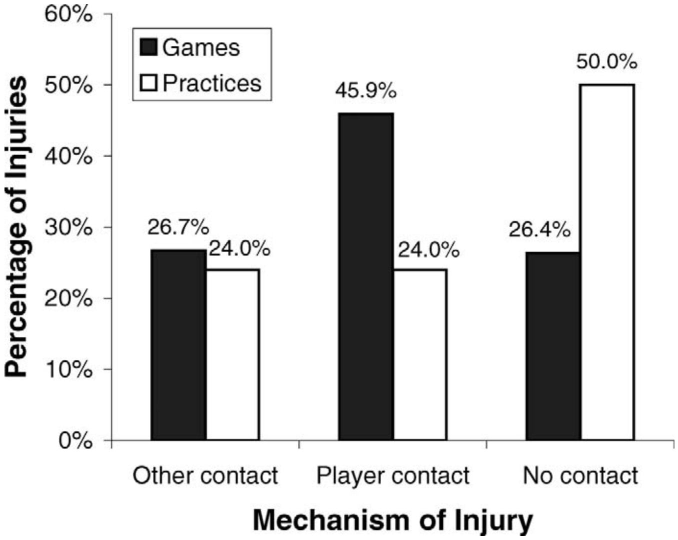


**Figure 2. Game and practice injury mechanisms, all injuries, men's lacrosse, 1988–1989 through 2003–2004 (n = 1921 game injuries and 2924 practice injuries). "Other contact" refers to contact with items such as balls, sticks, or the ground. Injury mechanism was unavailable for 1% of game injuries and 3% of practice injuries.**

in Divisions II and III increased significantly, the larger Division I programs fielded more players and averaged more practices per year. Similarities were noted in the number of games played and the number of participants per game across all 3 divisions.

Over the sample period, athletes were 4 times more likely to sustain injuries in games than in practices. These findings are similar to those of Hinton et al,[3] who reported a higher game-to-practice injury ratio in high school–aged male lacrosse players. Injuries occurred more frequently in preseason practices than during regular-season practices and more frequently during regular-season games than during postseason games.

The higher number of game injuries due to contact mechanisms is to be expected. The intensity of play is greater in games than in practices, when the exposure is likely divided between drills and scrimmages that are similar to game conditions and noncontact drills, instruction, and conditioning. This concept is supported by the fact that 60% of all injuries that occurred in games were due to a contact mechanism, with 50% of those occurring within the 25-yd line, where players have less room to move and where the game is a bit slower, more confined, and more subject to contact. This contact with other players likely leads to the higher rate of concussions in games, with nearly 80% of concussion injuries being due to contact with other players (Figure 5).

## Rule Changes, Prevention, and Interventions

The highest injury rate was noted during preseason games, with the lowest being noted during postseason games. As lacrosse players progress through the season, improve their conditioning, and accommodate for increased game and practice intensity, they are less likely to sustain an injury severe enough to warrant missed practices or games. To reduce the number of preseason injuries, it may be valuable to require a period of supervised, no-contact conditioning, similar to the "no pads" period mandated during preseason football, before beginning lacrosse-specific drills and practices.[4]

The lower rate of injury in the postseason relative to the regular season may be due to both reduced emphasis on training to improve conditioning and the importance of postseason games. Athletes may be less likely to miss important postseason games for injuries that might lend themselves to rest or missed practices or games during the regular season. Moreover, injuries sustained in the postseason are less likely to be reported, as there are no games or practices to miss after the last postseason game and the end of the season. In the case of lacrosse, the postseason often concludes after the end of the spring semester; players are likely to return to their hometowns rather than remain at school to receive treatment and medical follow-up, as they would during the season.

In 2000, a rule change was instituted in college lacrosse to protect players near the crease, where approximately 1 in 4 game injuries occurs (Figure 4). The "dive" rule prohibited offensive players from leaving their feet to shoot the ball and land in the goal crease. Although the rule was designed to protect the goaltenders from collisions with diving players, our experience is that this rule may also provide protection to the offensive player. In many cases, the defense of the dive was for a defensive player to check the diving, attacking player in midair before he released the shot. These defensive collisions

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

| Body Part | Injury Type | Frequency | Percentage of Severe Injuries | Most Common Injury Mechanism |
|---|---|---|---|---|
| Games (21.0% of all injuries required 10+ days of time loss) | | | | |
| Knee | Internal derangement | 108 | 27.3 | No contact |
| Shoulder | Acromioclavicular joint injury | 29 | 7.3 | Player contact |
| Ankle | Ligament sprain | 28 | 7.1 | No contact |
| Upper leg | Muscle-tendon strain | 22 | 5.6 | No contact |
| Other | | 209 | 52.8 | |
| Total | | 396 | | |
| Practices (21.0% of all injuries required 10+ days of time loss) | | | | |
| Knee | Internal derangement | 125 | 20.5 | No contact |
| Ankle | Ligament sprain | 73 | 11.9 | No contact |
| Upper leg | Muscle-tendon strain | 51 | 8.3 | No contact |
| Other | | 362 | 59.2 | |
| Total | | 611 | | |

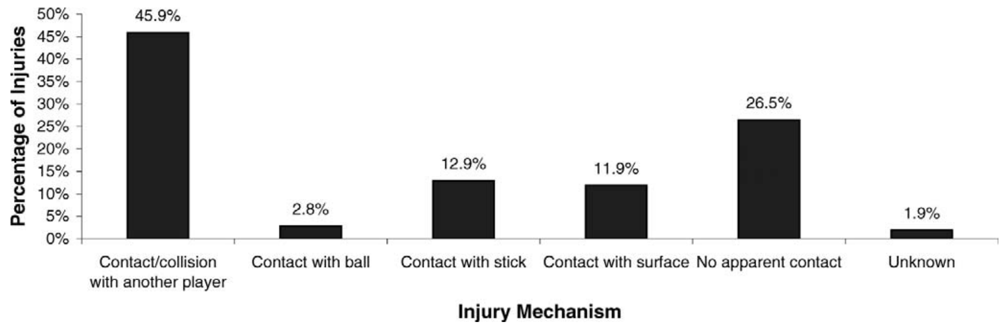


**Figure 3. Sport-specific game injury mechanisms, men's lacrosse, 1988–1989 through 2003–2004 (n = 1921).**

resulted in face lacerations, shoulder separations, contusions, and concussions.

Over the last 50 years, the biggest change in protective equipment has been the introduction of the contemporary lacrosse helmet. Similar in shape to a kayaking helmet, the lighter, less bulky style of the helmet was designed to provide improved vision and more cervical mobility. Caswell and Deivert[5] tested the ability of 2 helmets with the contemporary design and 2 helmets with a more traditional design to attenuate front-impact and rear-impact forces. Although the newer helmets attenuated rear-impact forces better than the traditional designs, they did a poorer job of attenuating forces from the front. Moreover, impact forces increased for all 4 helmets with 10 impacts, indicating that the helmets' ability to protect the players decreased with use.

We examined the rate of concussions before and after the widespread adoption of the contemporary design helmet, which occurred during the 1996–1997 season. If the contemporary helmet design better protected athletes from concussions, we would have expected the rate of concussions to decrease beginning in the 1996–1997 season. However, this is not what we found. The rate of reported concussions during both practices and games was significantly higher after the introduction of the new helmet. It is unclear why this increase in the concussion rate occurred. One possible explanation is that the early design of the contemporary helmet consisted of a hard Styrofoam (The Dow Chemical Co, Midland, MI) liner covered by a plastic shell. This design is common in rafting and kayaking, in which the purpose of the helmet is to protect the user from a serious head injury after a single severe impact on rocks or other hard surfaces. In lacrosse, the helmet needs to protect the player from multiple severe collisions with another player or the ground throughout games, practices, and the season. It is questionable whether this type of helmet is well suited for that purpose.

Location of impact may be another factor explaining the disparity in concussion rate. The contemporary helmets dissipated forces to the rear of the head better than the older helmet designs but did a poorer job with forces to the front of the head. It is possible that concussions in men's lacrosse occurred more frequently as a result of posterior impacts. If this was the case, the contemporary-designed helmet may have been less able to protect the player's head from that impact. It is impossible to know the role of the impact direction in the rate of concussions, as this question was not part of the present study. Also unknown is whether other mechanisms of concussion, such as rapid cervical side bending, rotation, or flexion-extension, were more likely to occur with one helmet design compared with another.

Several possible explanations exist for the difference in head injuries before and after the 1996–1997 seasons. One may be that the helmet design did not protect the athletes from concussions as well as the older models. Caution must be used in making this assumption, as the present analysis did not control for the use of different types of helmets, nor did it specifically relate the type of helmet use to injury rate. Also of note is the fact that the mid 1990s were a period of significant research into the detection and management of concussions in general, and the increased injury rate may be due to these improved methods of detection. It is also not known whether the contemporary helmet type offered better protection from other injuries to the eyes and face. However, based on these findings, further analysis of how different helmet designs may protect athletes from concussions resulting from front, rear, side, and cervical rotating or side-bending mechanisms is warranted.

## Areas of Future Research

Several areas of research may help identify ways to reduce the number of injuries in male collegiate lacrosse players. Two areas in particular address the player's protective equipment, which, with the exception of helmet design, has not evolved significantly over the last generation. First, future researchers need to determine if the change in helmet design to improve player performance also improves player safety. Further studies on the mechanisms of concussion in men's lacrosse and the ability of new helmet designs to attenuate forces involved with these mechanisms will help coaches, equipment managers, and parents make purchases based on a helmet's safety profile and ability to reduce injury risk.

Second, acromioclavicular joint injuries accounted for 5% of game injuries and 2% of practice injuries. The lacrosse shoulder pad is much lighter and less bulky than the shoulder pads worn in football and hockey. Unlike the ice hockey shoulder pad, the lacrosse shoulder pad has not undergone the same evolution to better cover and protect the joint over the last 30 years. Further investigation into the design and performance of the lacrosse shoulder pad may produce a lightweight pad that offers mobility, range of motion, and improved acromioclavicular joint protection. Any redesign may also include pads specific to certain positions: for example, the addition of chest protection for defensemen, who often face shooters and may be at increased risk of serious injury if struck by a stick or the ball during a shot or pass. Of specific interest is whether a practical and effective protective device can be developed to address the small but finite risk of catastrophic commotio cordis events due to chest impart from a lacrosse ball or stick.

Finally, because the rate of injuries is highest in the presea-

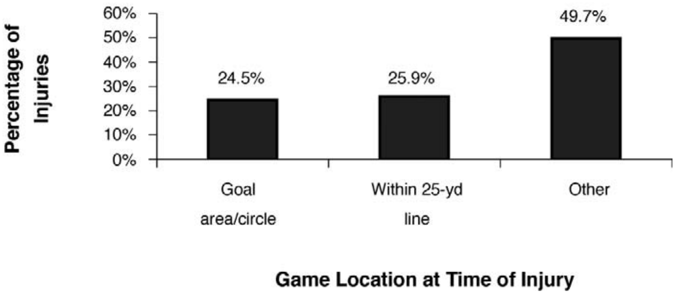


**Figure 4. Location at time of game injury, men's lacrosse, 1996–1997 through 2003–2004 (n = 1079). The goal area/circle is exclusive of the area within the 25-yd line on a regulation-size field.**

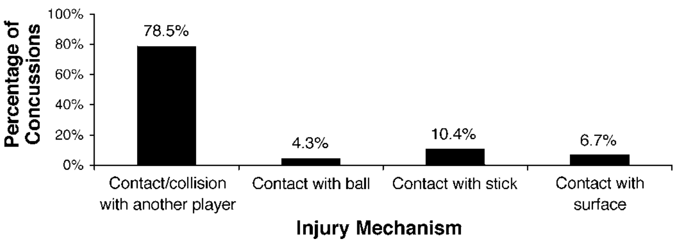


**Figure 5. Game concussion injury mechanisms, men's lacrosse, 1988–1989 through 2003–2004 (n = 165).**

son, it is important to develop and validate training protocols that improve the athletes' conditioning while preparing them for the rigors of early-season lacrosse practices and games. The 2003 NCAA preseason football model that initially limits the type of equipment worn and multiple sessions per day to enhance acclimatization may be a valuable template to consider.[5]

## 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.

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