

# Video Incident Analysis of Head Injuries in High School Girls' Lacrosse

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**Background:** Knowledge of injury mechanisms and game situations associated with head injuries in girls' high school lacrosse is necessary to target prevention efforts.

**Purpose:** To use video analysis and injury data to provide an objective and comprehensive visual record to identify mechanisms of injury, game characteristics, and penalties associated with head injury in girls' high school lacrosse.

**Study Design:** Descriptive epidemiology study.

**Methods:** In the 25 public high schools of 1 school system, 529 varsity and junior varsity girls' lacrosse games were videotaped by trained videographers during the 2008 and 2009 seasons. Video of head injury incidents was examined to identify associated mechanisms and game characteristics using a lacrosse-specific coding instrument.

**Results:** Of the 25 head injuries (21 concussions and 4 contusions) recorded as game-related incidents by athletic trainers during the 2 seasons, 20 head injuries were captured on video, and 14 incidents had sufficient image quality for analysis. All 14 incidents of head injury (11 concussions, 3 contusions) involved varsity-level athletes. Most head injuries resulted from stick-to-head contact ( $n = 8$ ), followed by body-to-head contact ( $n = 4$ ). The most frequent player activities were defending a shot ( $n = 4$ ) and competing for a loose ball ( $n = 4$ ). Ten of the 14 head injuries occurred inside the 12-m arc and in front of the goal, and no penalty was called in 12 injury incidents. All injuries involved 2 players, and most resulted from unintentional actions. Turf versus grass did not appear to influence number of head injuries.

**Conclusion:** Comprehensive video analysis suggests that play near the goal at the varsity high school level is associated with head injuries. Absence of penalty calls on most of these plays suggests an area for exploration, such as the extent to which current rules are enforced and the effectiveness of existing rules for the prevention of head injury.

**Keywords:** high school; head injury; concussion; sports; girls' lacrosse

Comprehensive assessment of game play and mechanism of head injury in scholastic sport is critical because of serious implications of head injury in sport,<sup>10,11,13,14,18</sup> especially in sports that are growing in popularity. Since its origins in 1926, participation in girls' lacrosse has increased in the United States at the youth, high school, and collegiate level, with a 10-year growth rate of 219%

reported in 2008.<sup>21</sup> Despite having shared origins, boys' lacrosse and girls' lacrosse have evolved into 2 distinct sports. Girls' lacrosse does not permit intentional stick or bodily contact, whereas the boys' sport permits such contact. Although girls' lacrosse requires protective eyewear, rules do not mandate the use of other protective equipment such as the helmet, shoulder and arm pads, and gloves used in the men's game. Girls' lacrosse has been reported to have higher rates of head and facial injuries than those in boys' lacrosse.<sup>15</sup> Similarly, a 2005 study of high school lacrosse injuries identified sport-related concussion as the fifth most prevalent injury among the girls' lacrosse players.<sup>12</sup> These studies, combined with increased public awareness of concussion in girls' lacrosse<sup>8</sup> and anecdotal reports of increasingly aggressive game play,<sup>5,9</sup> illustrate a need to better understand head injuries in girls' lacrosse.

Previous reports of head injury in girls' lacrosse have relied on eyewitness reporting to assess game play and injury mechanism.<sup>6,7,12,15</sup> No study has yet used video analysis to objectively examine comprehensive game play characteristics, including location of injury on the field, number of players involved, field conditions, and game score, to help characterize the play in which head injury

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One or more of the authors has declared the following potential conflict of interest or source of funding: Funded in part by a grant from the National Operating Committee on Standards for Athletic Equipment and from the US Lacrosse Sports Science & Safety Committee. The funding organizations had no other role in the study.

occurred. Using video analysis, injury mechanism can also be assessed comprehensively in terms of contact or noncontact, biomechanics associated with injury events, and possible involvement of a secondary event such as ground impact after initial injury. Video analysis can capture detail for analysis where an event occurs in a fraction of a second and may not be accurately reported by the injured party, parent, coach, or other observer.

We aimed to comprehensively assess situations of game play and injury mechanism to help determine where future injury prevention efforts, if any, might best be focused. Our purpose was to use video incident analysis to comprehensively evaluate situational characteristics of game play and injury mechanisms of head injury in high school girls' lacrosse.

## MATERIALS AND METHODS

Institutional review board approval was obtained. Data were prospectively gathered during the spring lacrosse season for each of the 25 high schools in a public school system over 2 competitive seasons, 2008 and 2009. Participants consisted of approximately 2500 female athletes between the ages of 14 and 18 years participating in varsity (25 teams) and junior varsity (25 teams) high school girls' lacrosse. Data elements consisted of video footage and a sideline injury log for all head injury incidents. An incident was defined as any injury about the head or facial region (including concussion) evaluated by a certified athletic trainer and recorded in the sideline injury log. Video footage of game segments containing head injuries was identified by the researchers and analyzed using a lacrosse-specific incident analysis instrument (LIAI) developed by the investigators for this study (see Table 1 for further detail regarding content of the LIAI). To confirm agreement among observers, video and game incident log data were cross-referenced with electronic medical records (EMR) maintained by an on-site certified athletic trainer using Sports Injury Management Systems software (Flantech, Iowa City, Iowa). An overview of the methodological process can be seen in Figure 1. Video supplements are available in the online version of this article at <http://ajs.sagepub.com/supplemental/>.

### Data Collection

Video of all varsity and junior varsity girls' lacrosse games was collected at each of the 25 high schools. All home contests (529) at each high school were digitally recorded by a trained videographer using a standard-definition 35-mm miniDV camcorder (Panasonic Corporation of North America, Secaucus, New Jersey) in SP mode, mounted on a standard 53-inch tripod, and recorded on a 90-minute miniDV cassette tape. All game footage was shot from the highest accessible elevation (such as the press box) and centermost position (midfield line) on the side of the lacrosse field having the team benches. Videographers were instructed to maintain a wide-angle shot panning left or right as necessary to keep game play

surrounding the ball in the center of the field of view and framing approximately one third of the length and the entire width (sideline-to-sideline) of the playing field. All videographers were also equipped with a game incident log and a 2-way radio to permit communication with the home team's certified athletic trainer on the sideline. All on-field injuries were documented in the game incident log. In addition, all injuries reported to or identified by the athletic trainer were immediately communicated to the videographer, who documented the approximate game time, score, and nature of the injury (mechanism and bodily location) in the game incident log. At the conclusion of each game, the videographer and certified athletic trainer convened to confirm that all reportable incidents were represented and appropriately classified in the game incident log based on the diagnosis of the certified athletic trainer.

Before the 2008 and 2009 seasons, all videographers underwent a training session from a professional videographer to become acquainted with the operation of the equipment and to familiarize themselves with video collection procedures. At the conclusion of the training session, all videographers performed a practice video collection session and received feedback on their technique from the professional videographer.

### Incident Analysis

The protocol for analyzing video of all game incidents identified as having a potential injury was developed by the authors based on work in Australian Rules Football and European Football using an incident analysis approach described by Appleby and Dawson<sup>3</sup> and Andersen et al,<sup>1,2</sup> respectively. The current investigators collaborated with US Lacrosse officials to modify the methodologies of match analysis<sup>17</sup> and qualitative skill analysis described by McIntosh et al<sup>16</sup> to develop a unified framework to identify, characterize, and classify game play leading up to each head injury. The resulting instrument consisted of 53 descriptive coding items. Coding items consisted of game characteristics (eg, score, time of day, weather, venue, field type and condition) and incident descriptors (eg, game segment, injury mechanism, field location).

All videotapes identified in the game incident log as having a possible concussion or injury to the head/face were included in the analysis. Videotapes were reviewed and independently analyzed by 2 investigators, each with lacrosse experience and familiarity with girls' lacrosse rules. Next, for each injury, the researchers captured and uploaded each incident into StudioCode (Sportstec USA, Camarillo, California) video analysis software. The software enabled researchers to modify video characteristics (eg, speed and zoom) and create a sortable repository for injury incidents so that specific characteristics of each incident could be documented using the LIAI. Each incident consisted of approximately 30 seconds of game play before the injury and continued until play was resumed. After all incident video files were uploaded, a detailed analysis of each injury and the preceding 5 seconds of game play was conducted. Each incident was reviewed using a 3-

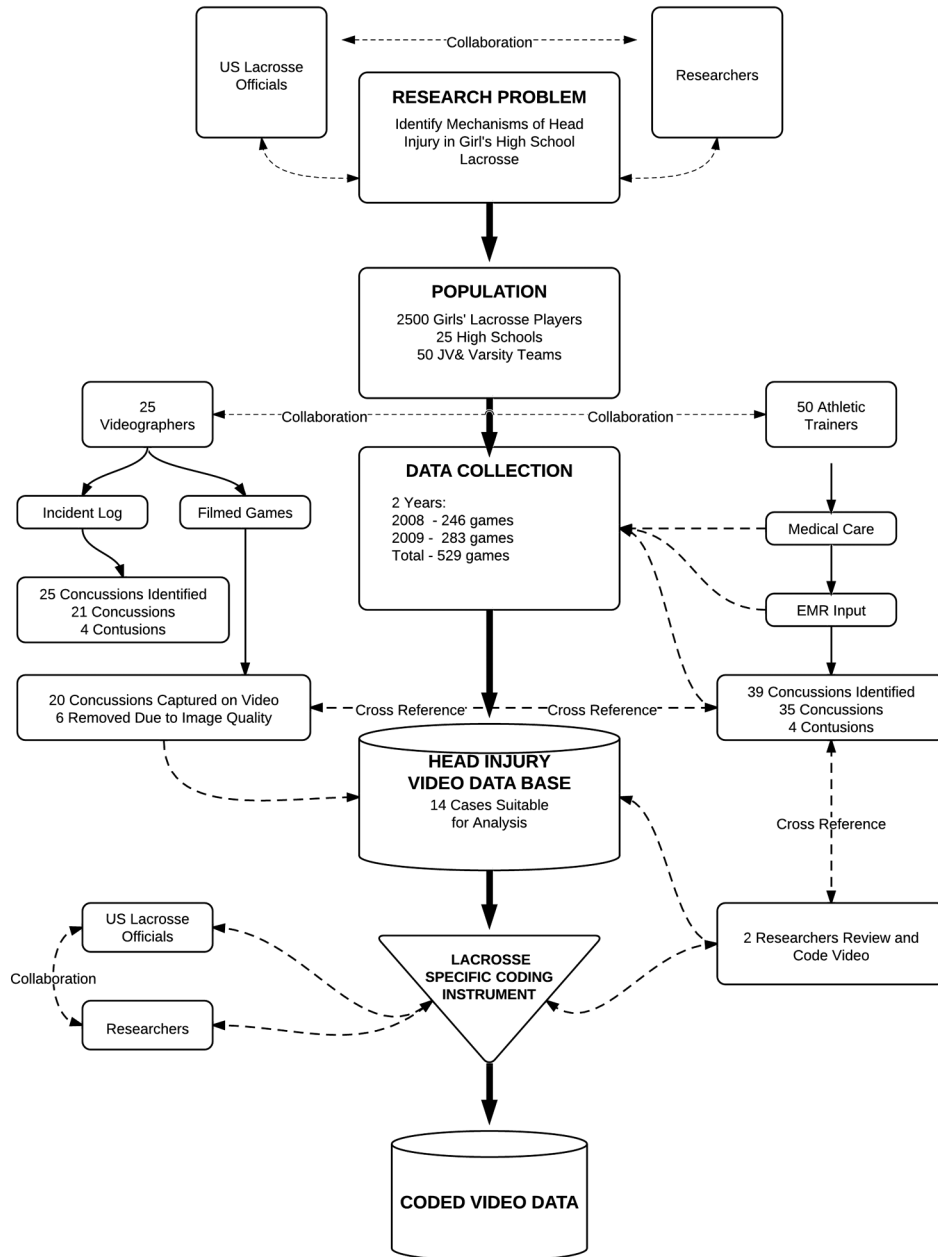


Figure 1. Methodological process.

step process: (1) the game play in the 5 seconds preceding the injury incident at normal speed, (2) the suspected injury incident at normal speed, and (3) the injury incident in slow motion (20% normal speed). Interrater reliability using the  $\kappa$  statistic was performed to determine consistency among raters.

RESULTS

In total, 529 girls' scholastic lacrosse games were captured on video for the 2008 (246 games) and 2009 (283

games) seasons. A review of the EMR revealed that 39 head injuries (35 concussions and 4 contusions) were diagnosed by the athletic trainers during the 2 seasons. Of these, 25 head injuries (21 concussions and 4 contusions) were recorded as game-related incidents. We captured video footage of 20 incidents (12 in 2008 and 8 in 2009) identified as game-related head injuries. Six of these incidents (5 in 2008 and 1 in 2009) were removed from the final analysis due to poor image quality (in 4 incidents, the image was obstructed by a player or official at the time of contact; 2 other incidents occurred partially out of camera frame). In total, 14 game-related head

TABLE 1  
Girls' Lacrosse Incident Analysis Instrument

Game Characteristic	Game Play and Incident Descriptors
Level of play	Nature of game play 5 seconds before game play
Environmental information (weather)	Game play associated with injury (offense, defense, transition)
Field information (type, quality, defects)	Injured player activity at time of injury (running, shooting, passing, catching, ground ball, etc)
Total injuries reported in game	Nature of the event (primary injury mechanism) causing injury (contact, noncontact, stick, body, object, etc)
Total fouls/infractions recorded in game	Nature of secondary injury mechanism (if present)
Location on field of injury	Description of contact (with intent, unintentional)
Final score of game	Number of players within 5 yd of injured player at time of injury
	Role of players involved (home team, away team, recipient, transgressor)
	Injured player position
	Penalty or illegal action called
	Score of game as time of injury
	General body location injured
	Specific location on head impacted
	Object striking injured player (stick, body part, ground, object)
	Game play immediately after the injury (stopped, delayed stoppage, continued)
	Injured player response to injury (continues playing, leaves game with/without assistance)
	Injury resolution (returned to game, removed from game, emergency medical services activated)

TABLE 2  
Characteristics of Head Injuries  
in Girls' Lacrosse, 2008-2009

Characteristic	n	%
Level of play		
Varsity	14	100
Junior varsity	0	0
Field location		
Attack	11	79
Inside 12-m arc	10	71
Inside 8-m arc	6	43
Midfield	3	21
Injured player position <sup>a</sup>		
Attack/home	6	43
Midfield	2	14
Defense	5	36
Injured player activity		
No possession	9	64
Loose ball	4	27
Defending shot	4	27
Face-off/draw	1	7
With possession	5	36
Running with ball	2	14
Shooting ball	2	14
Passing	1	7
Injury mechanism		
Stick (unintentional)	5	36
Stick (intentional)	3	21
Body (unintentional)	3	21
Body (intentional)	1	7
Ball	1	7
Undetermined	1	7
Nature of head injury		
Concussion	11	79
Contusion	2	14
Laceration	1	7

<sup>a</sup>One case player position was unknown.

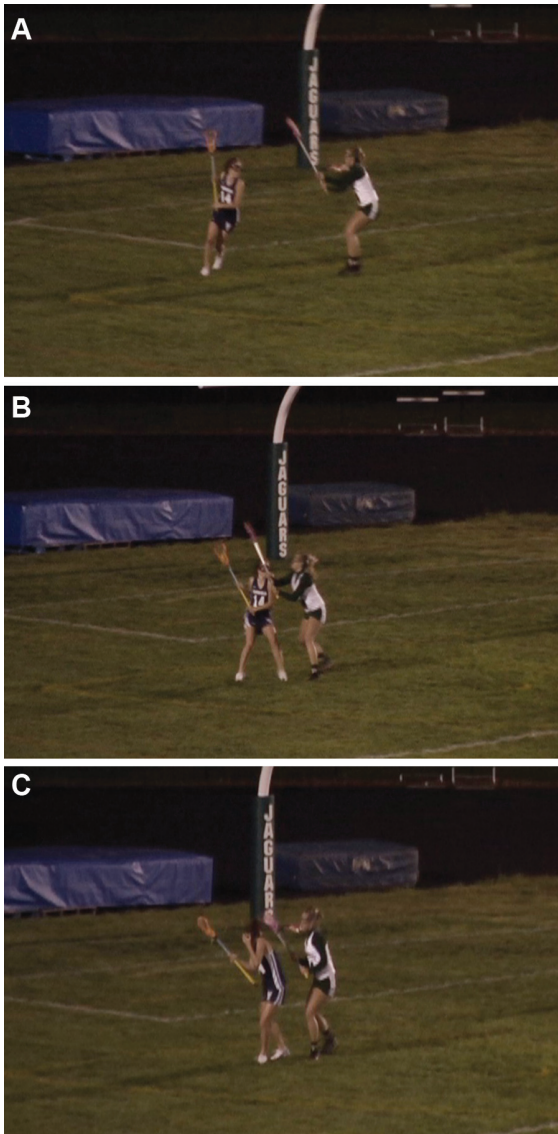
injury incidents were analyzed using the LIAI. Interrater agreement was high ( $\kappa = 0.79$ ), with 98% agreement in the investigators' observations of game play and incident descriptors (see Table 1).

Eleven (79%) of the 14 incidents were identified by the athletic trainer to be a concussion (Table 2). All head injuries involved varsity-level athletes. Half ( $n = 7$ , 50%) of the head injuries occurred in the first quarter of the season, with 9 incidents (64%) occurring on grass compared with 5 (36%) on turf. Weather conditions were clear in all cases, and field conditions were good in 11 (79%) of 14 cases analyzed.

The majority of head injuries resulted from stick contact to the head ( $n = 8$ , 57%). Most stick contact (5/8) resulting in head injury was characterized as unintentional. The regions of the head most frequently struck were the face ( $n = 6$ ) and side of head ( $n = 3$ ). Most stick-related head injuries occurred in front of the goal ( $n = 5$ ), with 4 occurring within the 8-m arc. Within the 8-m arc, 3 head injuries were the result of being unintentionally struck in the head by a stick while defending a shot. Stick-related injuries accounted for 5 of the 11 concussions, with 2 concussions resulting from intentional stick check. Two of the 8 cases of stick-related contact resulted in a penalty. A typical stick contact scenario resulting in head injury is shown in Figure 2 and in Video Clip 1 (available online).

The second most frequent injury mechanism was body-to-head contact ( $n = 4$ ). In each case, the injured player was attempting to retrieve a loose ball and collided with an opponent's head, shoulder, or stick. Three of the 4 bodily contacts were characterized as unintentional collisions. In addition, a secondary impact of head to ground may have contributed to 3 concussive events. No cases of bodily contact associated with a head injury resulted in a penalty. A typical bodily contact scenario resulting in head injury is shown in Figure 3 and in Video Clip 2 (available online).





**Figure 2.** A typical stick contact scenario resulting in head injury. (A) Player on offense being guarded by defensive player. (B) Defensive player out of control and strikes offensive player unintentionally. (C) Player injured and game continues; no penalty called.

In 9 of the 14 cases, the injured player did not have ball possession at the time of injury. Of these, loose ball ( $n = 4$ ) and defending a shot ( $n = 4$ ) scenarios occurred most frequently. In 5 cases, head injuries occurred when the injured player had possession of the ball (running, dodging, catching, or shooting). An examination of game play characteristics associated with head injury revealed the attack area to be the region of the playing field where head injuries most commonly occurred ( $n = 11$ , 79%), followed by the midfield area ( $n = 3$ , 21%). Within the attack area, 10 head injuries (71%) occurred inside of the 12-m arc, and 7 (64%) occurred in front of the goal. A review of the 5 seconds of play preceding injury revealed that the



**Figure 3.** Typical bodily contact scenario resulting in head injury. (A) Two players run after loose ball. (B) Both players out of control and collide. (C) Player injured and game stops; no penalty called.

injured player's team was on offense in 7 of the 14 cases and that play was unsettled in 5 cases. The most frequently injured player positions were attack ( $n = 6$ , 43%) and defense ( $n = 5$ , 36%). An examination of the score between the injured player's and opponent's teams at the time of injury suggested no relationship between game score and head injury.

## DISCUSSION

Video analysis using a detailed assessment instrument allowed comprehensive objective assessment of head

injuries in 2 seasons of high school girls' lacrosse. Head injuries, regardless of type, most often resulted from stick-to-head contact while defending a shot and from bodily contact while competing for a loose ball. The majority of head injury cases were characterized by unintentional contact, and in nearly all cases, no penalty was called. Furthermore, all head injuries occurred at the varsity level. These findings suggest that the biggest factors associated with head injury in girls' lacrosse are the high skill level and intensity associated with varsity play and activities associated with shooting, defending a shot, and competing for a loose ball.

These findings provide added objective support for those of previous studies reporting stick or ball contact as the chief mechanisms causing head and facial injury among girl lacrosse players.<sup>7,12,15</sup> The current study using video analysis supports these findings by demonstrating that the primary mechanism of head injury during games in high school girls' lacrosse was stick contact to the face or side of head between 2 opposing players. A retrospective examination of insurance claims data of US lacrosse members reported that the majority of all injuries were to attacking players and most frequently resulted from unintentional but legal body-to-body and stick-to-body contacts while ball handling and driving toward the goal in a settled offense situation.<sup>4</sup> In contrast, our study revealed most head injuries occurred when the injured player did not have ball possession.

Lincoln et al<sup>15</sup> noted that high school girls were most commonly injured from stick-to-body contact while possessing the ball. Suggesting that improved player skill might decrease injury, they proposed skills training in stick handling as an intervention. Our findings suggest limited skill is not a factor in head injury in that all injuries occurred at the varsity level, although junior varsity teams played roughly the same number of games. This finding supports a report on highly skilled players in collegiate women's lacrosse in which 56% of above-the-neck game injuries resulted from stick contact.<sup>6</sup> These findings suggest a possible association between higher skill level play or intensity and head injuries in girls' high school lacrosse.

Carter et al<sup>4</sup> reported that the majority of bodily injuries resulting from stick-to-body or body-to-body contacts were considered legal. Our findings were similar in that a penalty was not called in 11 of the 14 head injury cases analyzed. A possible explanation for this is that most head injuries in girls' lacrosse result from legal play. However, the 2010 Official Rules for Girls and Women's Lacrosse<sup>20</sup> include several rules pertaining to stick-related fouls in the area of the goal that are designed to reduce the risk of injury. These rules focus on check to the head, illegal placement of a defensive player in front of the goal, and dangerous stick follow-through after shooting by an attacking player. In theory, enforcement of these rules should protect both the offensive ball carrier and the defender from being injured by unintentional stick contact. However, only 2 of the 8 stick-related head injuries resulted in penalties in the current study. These findings suggest that further research is needed to address whether these rules are being enforced appropriately, whether coaches

and officials have adequate understanding of the rules, and whether the rules provide the protection originally intended.

In addition, rule changes were implemented for 2010-2011 to increase the severity of red and yellow cards to facilitate a greater responsibility for safety across the player, coach, and team. For example, high school players who receive a red card must sit out of the team's next two games, whereas youth players who receive a red card as a result of a check to the head are required to sit out the team's next game.<sup>20</sup>

Girls' lacrosse is an incidental contact sport and thus has little mandatory protective equipment, other than eyewear and a mouthguard.<sup>4</sup> Our findings support earlier observational studies suggesting that a significant percentage of head injuries in girls' lacrosse result from unintentional stick contact to the head.<sup>7,12,15</sup> Using video analysis, we revealed that most head injuries resulted from unintentional stick contact while defending a shot. This finding adds to the prior literature and suggests that head injury in girls' lacrosse may be an indirect consequence of play in which players position themselves in hazardous situations, either purposely or inadvertently. At present, the 2010 Official Rules for Girls and Women's Lacrosse<sup>20</sup> permit the use of soft headgear by all players. Soft headgear is designed to prevent only contusions and lacerations to the skull and is rarely worn by players. It is unknown whether requiring use of a protective helmet, in combination with existing eyewear or a face shield attached to the helmet, would help reduce head injuries in girls' lacrosse. Presently, strong opinions exist on both sides of this issue, with some observers contending that helmets could change the nature of the girls' game and possibly lead to increased aggressive play and more injury.<sup>15,19</sup> Research is needed regarding intended and unintended consequences of helmets in girls' lacrosse.

Our study is limited in that our definition of head injury included only game injuries occurring during 2 consecutive seasons of girls' high school lacrosse in a single school district, and therefore we did not capture head injuries occurring during practice sessions. Our sample size limits the confidence to generalize these findings more broadly to all scholastic and collegiate women's lacrosse. However, our findings regarding injury mechanism were consistent with those of previous investigations.<sup>7,12,15</sup> Future research should examine head injuries in girls' lacrosse using a larger and randomly selected sample. We were able to analyze only 14 of 25 game-related head injuries, partly because the single-camera view of the injury play was obscured by officials or other players in 6 cases. Although our instrument characterized both primary (impact to the head or body) and secondary (impact to ground) head injury mechanisms, we could not definitively assess which impact caused the injury. Concussion may have been undetermined and/or underreported in the present study. The EMR revealed 25 game-related head injuries, whereas we identified only 20 such injuries using video analysis. The discrepancy may be related to delayed onset of symptoms or reporting of concussion to the athletic trainer. The measurement instrument has not been

validated, but it was developed with lacrosse expertise from US Lacrosse and the US Lacrosse Safety Committee and reflects expert opinion.

## CONCLUSION

Comprehensive video analysis suggests that aggressive play near the goal at the most skilled scholastic level is associated with head injuries. Absence of penalty calls on most of these plays suggests an area for exploration, such as the extent to which current rules are enforced and how effective existing rules are for the prevention of head injury.

## ACKNOWLEDGMENT

The authors thank the many videographers and certified athletic trainers for their assistance with data collection and Lyn Camire, MA, ELS, for editorial assistance.

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