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Rule Modifications to Reduce Checking-Related Injuries in High School Boys' Lacrosse

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Context: The National Federation of State High School Associations previously implemented 2 lacrosse rule modifications: Rule 5.4 in the 2012–2013 academic year to heighten the penalty for a head or neck hit to the head, face, or neck (HFN) and Rule 5.3.5 in the 2013–2014 academic year to minimize body checking.

Objective: To determine if the rates of overall injury, HFN injuries, and concussions due to intentional contact (checking) differed for boys' high school lacrosse players after Rule 5.4 and 5.3.5 modifications were enacted.

Design: Descriptive epidemiology study.

Setting: Web-based online surveillance system.

Patients or Other Participants: Boys' high school lacrosse players during the 2008–2009 to 2016–2017 seasons whose teams involved athletic trainers participating in the High School Reporting Information Online sports injury-surveillance system.

Intervention(s): Rule 5.4 in the 2012–2013 academic year increased the penalty for any intentional hits to the HFN, and Rule 5.3.5 in the 2013–2014 year eliminated body checking to a player in a defenseless position.

Main Outcome Measure(s): Overall, HFN, and concussion injury rate ratios (IRRs) by checking mechanism; overall and checking-related injury ratios by competitions and practices.

Results: A decrease was shown in checking-related HFN injuries (IRR = 0.29, 95% CI = 0.13, 0.65) and checking-related concussions (IRR = 0.29, 95% CI = 0.12, 0.70) during practices in the seasons after both rule modifications were imposed, but no decreases occurred in any checking-related injuries during competitions. By injury mechanism, no decreases were evident after the Rule 5.4 modification. When both rule modifications (Rules 5.4 and 5.3.5) were enacted together, concussion rates due to delivering body checks (IRR = 0.51, 95% CI = 0.29, 0.91) and overall injury risk due to being body checked (IRR = 0.72, 95% CI = 0.53, 0.97) decreased.

Conclusions: When both Rule 5.4 and 5.3.5 modifications were in effect, concussion and overall injury risks decreased for the body checker and the player being body checked, respectively.

Key Words: epidemiology, body checking, concussion, injury rate ratio, injury prevention

Key Points

- Declines in injury rates as a result of being body checked and concussion rates due to delivering body checks were noted when Rule 5.4 and 5.3.5 modifications went into effect.
- When injuries in the 4-year period after both rule modifications were compared with those in the 4-year period before the modifications, the number of concussions due to delivering body checks decreased by 36.7% and overall injuries from being body checked decreased by 11.2%.
- Head-, face-, and neck-related injuries must still be addressed, whether through better enforcement or implementation of the rules, more effective protective headwear, or other policy interventions.

Participation in US high school sports reached an all-time high in recent years, with the increase in participants from 2016 to 2017 (7.96 million participants) being one of the largest recorded in the past decade.[1] According to the National Federation of State High School Associations (NFHS), lacrosse has experienced fast-growing numbers in team sport participation.[1,2] Data on participation was first collected by US Lacrosse in 2001, and over a 15-year period, participation increased by more than 225%.[2] A US Lacrosse 2016 participation survey estimated a high of 315 887 total high school lacrosse players, a 3.5% increase from the prior year.[2] This growth is also partly due to the considerable increase in the number of schools sponsoring lacrosse.[1] This increase in participation has raised concerns about increased injury frequency, especially in adolescent athletes.

The incidence of injuries during collision sports, such as lacrosse, is a major public health concern, with significant attention being paid to concussions. In the boys' game, body contact and stick checking are both legal at the high school level and can create additional risks for injuries. Authors of previous studies comparing the incidence of injuries across multiple sports have shown that high school boys' lacrosse has the third highest incidence rate of

Table 1. Rule Modification Summary

Rule Modification	Academic Year Implemented	Description or Purpose
5.4	2012–2013	Minimize intentional contact to the head or neck
5.3.5	2013–2014	Minimize the use of body checking

concussions (4.0 per 10 000 athlete-exposures [AEs])[3–5] and that being body checked, cross checked, or stick checked were the most common activities resulting in injuries.[6] More specifically, the head or face was the most frequently injured body site due to checking and being checked, while concussions were the most cited injury diagnosis.[7] According to Bartley et al,[7] lacrosse had the largest percentage of concussions resulting from checking and being checked (39.1% and 43.8%, respectively) compared with the percentage of concussions from intentional contact mechanisms in both football and ice hockey. As a result, head, face, or neck (HFN) injuries should receive particular attention given the high concussion rates resulting from these injury mechanisms.

To reduce the injury risk to high school boys' lacrosse athletes, the NFHS revised checking-related game play. The rules are summarized in Table 1. First, Rule 5.4 was revised to state that any intentional hits to the head would be deemed a higher foul, changing the previous penalty of 2 minutes to full-time–serving nonreleasable fouls. This rule was revised for the 2012–2013 academic year in the hope that a more severe penalty would affect the behavior of players and coaches; the rule stated that any contact to the head or neck, including initiation of such contact by an offensive player in possession of the ball, would be a violation of this rule.[8] Second, Rule 5.3.5 was enacted for the 2013–2014 academic year to minimize the risk of injury due to body checking by expanding the definition of illegal body checking, resulting in an increased duration of nonreleasable foul ejection. This rule stated that a body check targeting a player in a defenseless position was illegal. Examples of this include "body checks to any player from his blind side, who has his head down playing a loose ball, and who turned away to receive a pass."[9(p77)] Since these rules were implemented, their effects on injury incidence have not yet been evaluated. Therefore, the primary objective of our study was to determine if checking-related rule modifications were associated with changes in the incidence of injuries, including concussions, due to intentional contact (body or stick checks).

METHODS

Data from the internet-based data-collection tool of the National High School Sports-Related Injury Surveillance Study, High School Reporting Information Online (HS RIO), were examined for the 2008–2009 to 2016–2017 academic years. First, the year after the Rule 5.4 modification (2012–2013) was compared with prior years (2008–2009 to 2011–2012), and second, the years in which Rule 5.4 and 5.3.5 modifications were in effect (2013–2014 to 2016–2017) were compared with the years in which neither was in effect (2008–2009 to 2011–2012). The methods of this Internet-based surveillance system have been reported previously[10–12] but are summarized here.

Data Collection

The HS RIO tool captures injury and AE data from a large sample of nationally representative high schools. In brief, National Athletic Trainers' Association–affiliated certified athletic trainers (ATs) with valid email addresses who were willing to participate in the study submitted online weekly reports of high school sport-related injuries.[10] The investigation began in the 2005–2006 academic year and involved 100 randomly selected schools categorized by US Census geographic location (Northeast, Midwest, South, or West)[13] and high school size (enrollment $\leq$1000 or $>$1000) into 8 strata. Originally, 9 sports were included in the sample. In 2008–2009, HS RIO expanded to capture additional sports (eg, boys' lacrosse) by allowing the random sample schools to collect data as well as enrolling additional schools (those not enrolled in the original sample) into a convenience sample. The current work consists of a convenience sample of all high school boys' lacrosse programs that provided data to HS RIO between 2008–2009 and 2016–2017.

For each reported injury, ATs completed a detailed injury report that consisted of athlete demographics (ie, age, height, weight), injury information (ie, site, diagnosis, severity), and injury event information (ie, activity, mechanism). Throughout the study period, ATs could review and update the submitted information as necessary.

Definitions of Exposure and Injury

An *AE* was defined as a single athlete participating in 1 competition or practice in which exposure to possible athletic injury occurred. An *injury* was defined as (1) occurring as a result of participation in a competition or practice, (2) requiring medical attention from an AT or physician, and (3) restricting the athlete's participation in the sport for at least 1 day beyond the injury date. However, any injury resulting in a fracture, concussion, dental injury, or heat illness was included regardless of participation-restriction time.

Statistical Analysis

Data analysis was conducted using SPSS (version 24; IBM Corp). We calculated injury frequencies, distributions, and rates per 1000 AEs. Descriptive analyses were used to examine distributions by event type (competition versus practice) as well as injuries specific to the HFN and concussion. We also assessed checking-only injuries, which included those injuries resulting from delivering a body or stick check or being body or stick checked.

Injury rate ratios (IRRs) were calculated to evaluate the effects of rule modifications across time periods. We considered 3 time periods: (1) before the rule modifications were in effect (2008–2009 to 2011–2012); (2) after the Rule 5.4 modification was in effect, but before the Rule 5.3.5 modification was in effect (2012–2013); and (3) after both rule modifications were in effect (2013–2014 to 2016–

Table 2. Checking-Related Competition and Practice Injuries by Time Period[a]

Injury Mechanism	2008–2009 to 2011–2012		2012–2013		2013–2014 to 2016–2017	
	No.	Injury Rate per 1000 AEs (95% CI)	No.	Injury Rate per 1000 AEs (95% CI)	No.	Injury Rate per 1000 AEs (95% CI)
Overall	943	2.26 (2.12, 2.41)	221	1.97 (1.71, 2.23)	1044	2.02 (1.90, 2.15)
Checking related	234	0.56 (0.49, 0.63)	60	0.53 (0.40, 0.67)	246	0.48 (0.42, 0.54)
Delivered body check	63	0.15 (0.11, 0.19)	19	0.17 (0.09, 0.25)	62	0.12 (0.09, 0.15)
Delivered stick check	23	0.06 (0.03, 0.08)	6	0.05 (0.01, 0.10)	18	0.03 (0.02, 0.05)
Received body check	89	0.21 (0.17, 0.26)	18	0.16 (0.09, 0.23)	79	0.15 (0.12, 0.19)
Received stick check	59	0.14 (0.11, 0.18)	17	0.15 (0.08, 0.22)	87	0.17 (0.13, 0.20)
Competition	572	4.45 (4.08, 4.81)	137	3.88 (3.23, 4.54)	649	4.21 (3.89, 4.54)
Checking related	173	1.35 (1.14, 1.55)	43	1.22 (0.85, 1.58)	190	1.23 (1.06, 1.41)
Delivered body check	45	0.35 (0.25, 0.45)	13	0.37 (0.17, 0.57)	49	0.32 (0.23, 0.41)
Delivered stick check	19	0.15 (0.08, 0.21)	6	0.17 (0.03, 0.31)	15	0.10 (0.05, 0.15)
Received body check	66	0.51 (0.39, 0.64)	11	0.31 (0.13, 0.50)	67	0.43 (0.33, 0.54)
Received stick check	43	0.33 (0.23, 0.43)	13	0.37 (0.17, 0.57)	59	0.38 (0.29, 0.48)
Practice	371	1.29 (1.16, 1.42)	84	1.09 (0.86, 1.32)	395	1.09 (0.98, 1.20)
Checking related	61	0.21 (0.16, 0.26)	17	0.22 (0.12, 0.33)	56	0.15 (0.11, 0.20)
Delivered body check	18	0.06 (0.03, 0.09)	6	0.08 (0.02, 0.14)	13	0.04 (0.02, 0.06)
Delivered stick check	4	0.01 (0.00, 0.03)	0	0.00	3	0.01 (0.00, 0.02)
Received body check	23	0.08 (0.05, 0.11)	7	0.09 (0.02, 0.16)	12	0.03 (0.01, 0.05)
Received stick check	16	0.06 (0.03, 0.08)	4	0.05 (0.00, 0.10)	28	0.08 (0.05, 0.11)

Abbreviation: AE, athlete-exposure.

[a] 2008–2009 to 2011–0212 was the time period before both Rule 5.4 (minimizing contact to the head) and Rule 5.3.5 (minimizing injuries due to body checking) modifications. During 2012–2013, Rule 5.4 was enacted, but Rule 5.3.5 was not. During 2013–2014 to 2016–2017, both modifications were enacted.

2017). Thus, for the analysis of the effects of the Rule 5.4 modification, injury rates in 2012–2013 were compared with those from 2008–2009 to 2011–2012. For the analysis of both rule modifications (Rules 5.4 and 5.3.5), injury rates in 2013–2014 to 2016–2017 were compared with those from 2008–2009 to 2011–2012; 2012–2013 was not considered, as only 1 rule modification was enacted during that time period.

The IRRs were first calculated for each specific event type to compare injury rates for overall injuries, overall checking-only injuries (delivering body or stick checks, or being body or stick checked), checking-related HFN injuries, and checking-related concussions. The IRRs were then determined for each type of checking-related injury for all injuries, HFN injuries, and concussions. All IRRs with 95% CIs that did not include 1.00 were considered statistically significant.

RESULTS

From 2008–2009 to 2016–2017, a total of 522 team-seasons of data were collected. Over the 9-year period, 2208 injuries were recorded, of which 540 (24.4%) were checking related (Table 2). Most checking-related injuries occurred during competitions (75.2%). The 540 checking-related injuries occurred during 1 044 865 AEs, leading to an overall checking-related contact-injury rate of 0.52/1000 AEs (95% CI = 0.47, 0.56). Among the 540 checking-related injuries, 144 injuries were from delivering body checks (26.7%), 47 injuries from delivering stick checks (8.7%), 186 injuries from being body checked (34.4%), and 163 injuries from being stick checked (30.2%). In addition, 222 injuries involved the HFN (41.1%), which included 167 diagnosed concussions (75.2% of all HFN injuries).

Before both rule modifications (2008–2009 to 2011–2012), 234 injuries were reported, for an injury rate of 0.56/1000 AEs (95% CI = 0.49, 0.63; Table 2). After the modification of Rule 5.4 but before the modification of Rule 5.3.5 (2012–2013), 60 injuries were reported, for an injury rate of 0.53/1000 AEs (95% CI = 0.40, 0.67). Lastly, after both rules were modified (2013–2014 to 2016–2017), 246 injuries were reported, for an injury rate of 0.48/1000 AEs (95% CI = 0.42, 0.54).

Effect of Rule Modification by Event Type and Injury Type

The competition and practice injury rates for each time period (after versus before the associated rule modifications) are stratified by event type in Figures 1 and 2. No differences existed between event type-specific injury rates in the season after the revision of Rule 5.4 versus before the rule modifications (2008–2009 to 2011–2012; Figure 1). After the modification of both Rules 5.4 and 5.3.5 (2013–2014 to 2016–2017), decreases in injury rates for practices were found for all injuries (IRR = 0.85, 95% CI = 0.74, 0.98), checking-related HFN injuries (IRR = 0.29, 95% CI = 0.13, 0.65), and checking-related concussions (IRR = 0.29, 95% CI = 0.12, 0.70); Figure 2). No differences were present in competition injury rates before and after the rule modifications. The changes in overall checking-related injury rates for competitions and practices each year are depicted in Figures 3 and 4, respectively. Given the limited amount of data available when separating injuries by competitions and practices for each year, the CIs in the figures were noted to be wide.

Effect of Rule Modifications by Checking Mechanism and Injury Type

Compared with the years before the modification of Rule 5.4 (2008–2009 to 2011–2012), no decreases occurred in injury rates from any checking mechanism during the 2012–2013 academic year, when the rule was modified (Table 3).

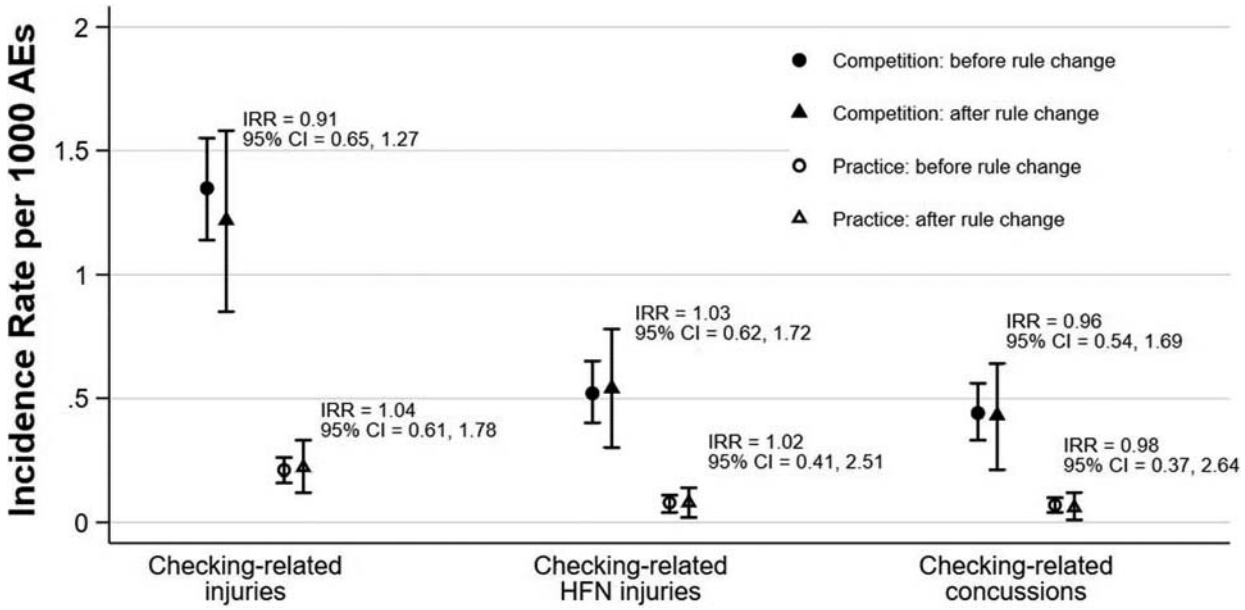

Figure 1. Competition and practice injury rates for overall checking-only injuries (delivering body or stick check or being body or stick checked); checking-related HFN injuries; and checking-related concussions by time period associated with Rule 5.4 for minimizing contact to the head. Overall IRRs for all injuries: competition (IRR = 0.87, 95% CI = 0.72, 1.05) and practice (IRR = 0.85, 95% CI = 0.67, 1.07). Abbreviations: AEs, athlete-exposures; HFN, head, face, or neck; IRR, injury rate ratio.

After the modifications of both Rules 5.4 and 5.3.5, a reduction in the concussion rate associated with delivering a body check was shown (IRR = 0.51, 95% CI = 0.29, 0.91; Table 4). The overall injury rate associated with being body checked also decreased (IRR = 0.72, 95% CI = 0.53, 0.97).

DISCUSSION

We evaluated the effects of modified rules on reducing the incidence of checking-related injuries in high school boys' lacrosse during the 2008–2009 to 2016–2017 seasons. Rule 5.4, modified for the 2012–2013 academic year, aimed to specifically minimize head and neck contact. In the 2013–2014 academic year, Rule 5.3.5 was modified to reduce intentional player-to-player collisions due to body checking of players in defenseless positions. Similar to prior authors,[5–7] we studied a large dataset of high school boys' lacrosse injuries. Concussion rates associated with delivering a body check and overall injury rates associated with being body checked decreased after both rules were modified (IRRs = 0.51 and 0.72, respectively). These

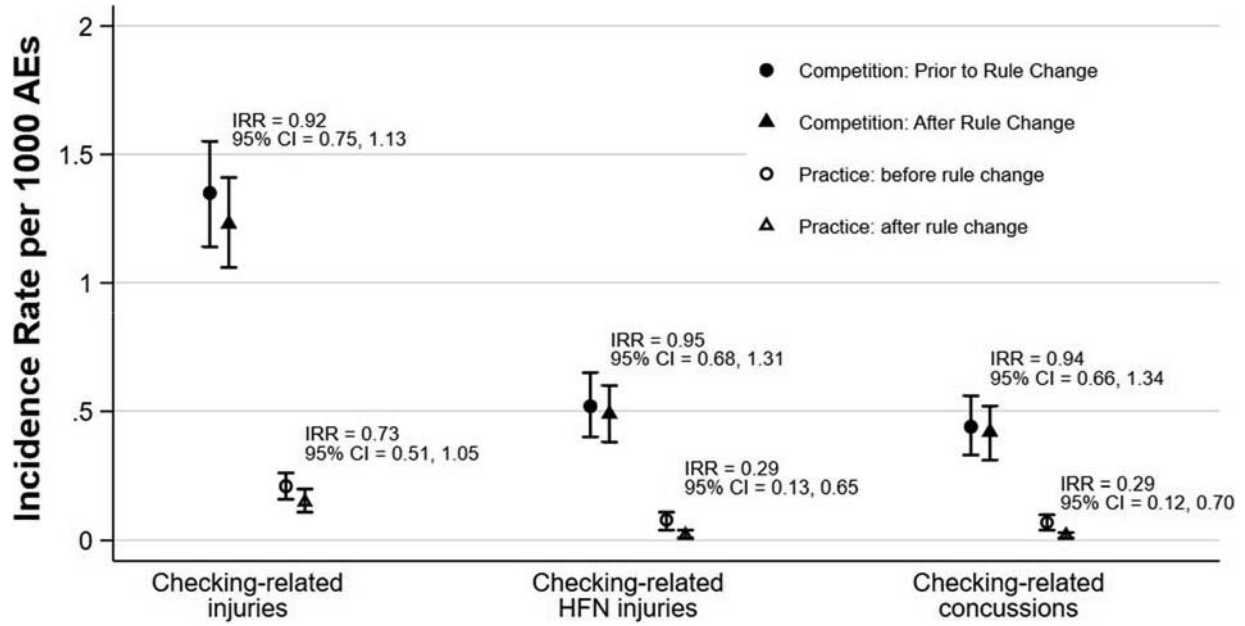

Figure 2. Competition and practice injury rates for checking-only injuries and concussions before and after the modifications of both Rule 5.4 (minimizing contact to the head) and Rule 5.3.5 (minimizing injuries due to body checking). Overall injury rate ratios for all injuries: competition (IRR = 0.95, 95% CI = 0.85, 1.06) and practice (IRR = 0.85, 95% CI = 0.74, 0.98). Abbreviations: AEs, athlete-exposures; HFN, head, face, or neck; IRR, injury rate ratio.

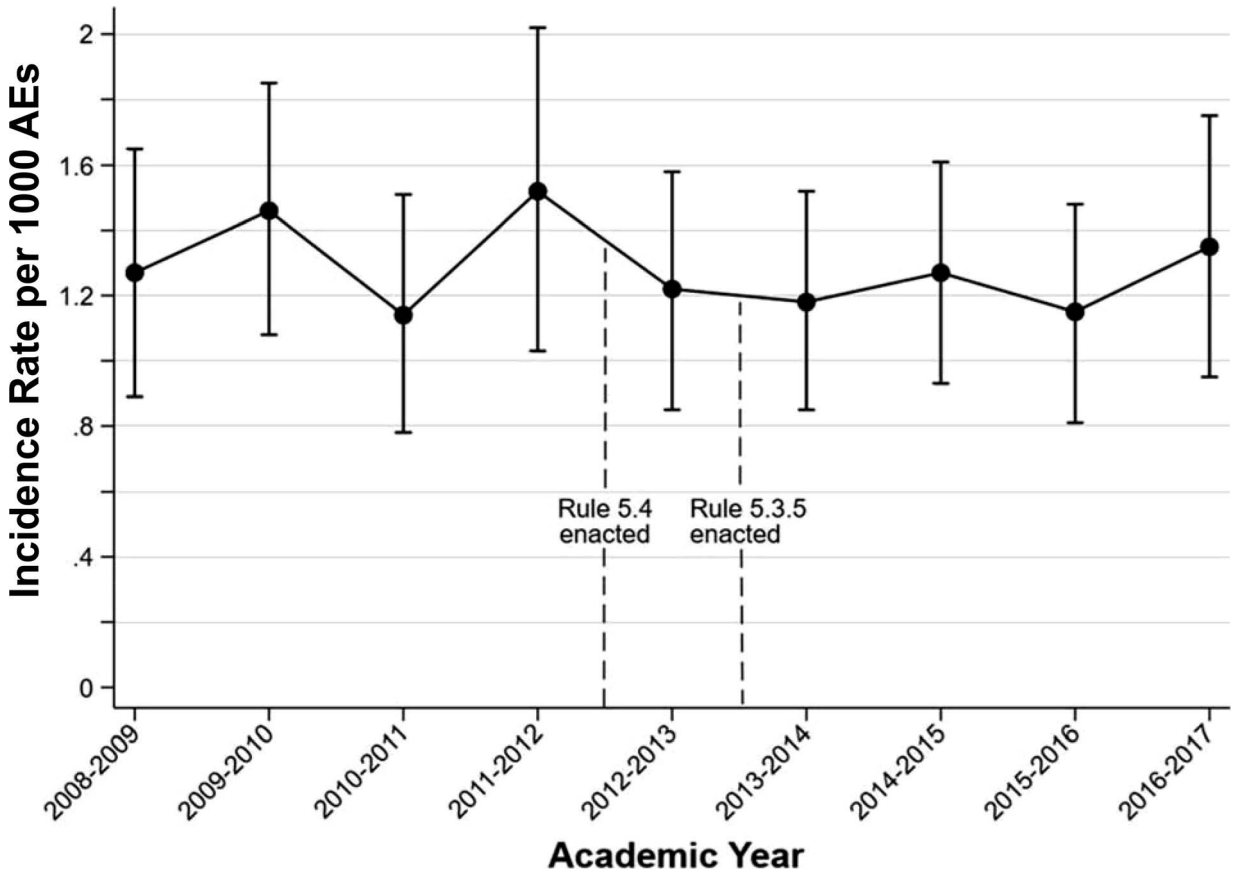

Figure 3. Competition injury rate changes over time after implemented rule modifications. Note: 2008–2009 to 2011–2012 was the time period before both Rule 5.4 (minimizing contact to the head) and Rule 5.3.5 (minimizing injuries due to body checking) modifications. During 2012–2013, Rule 5.4 was enacted, but Rule 5.3.5 was not. During 2013–2014 to 2016–2017, both rules were enacted. Abbreviation: AEs, athlete-exposures.

findings suggest that both rules were effective in reducing checking-related injuries.

Rule Modifications

Previous investigators[14–17] evaluated rule modifications in youth ice hockey that aimed to minimize checking- and other contact-related injuries. In contrast, research focused on rule modifications associated with checking and contact in lacrosse is lacking. We found that Rule 5.4 alone was not associated with decreases in injury incidences during the 2012–2013 academic year. This may have been due to insufficient power to detect a difference during that 1-year period. However, it is important to note that IRRs based on large injury counts, such as those comparing all injuries associated with checking or their specific strata, were close to the null (1.00), suggesting that Rule 5.4 may not have produced an immediate effect.

When considering the time period in which both Rule 5.4 and 5.3.5 modifications were enacted, we demonstrated a 42.8% reduction in concussion rates due to delivering a body check and a 28.6% overall injury rate reduction due to being body checked. It is possible that players delivering body checks became less aggressive to players in possession of the ball in an attempt to avoid penalties resulting from the rule modifications. A violation of each rule resulted in a minimum 2- or 3-minute nonreleasable penalty, which could have reinforced the need to eliminate hits to the HFN (Rule 5.4) and other potential body-checking-related injuries (Rule 5.3). Yet we were not able to independently assess the effects of these rules. That is, we were unsure whether Rule 5.4 had a delayed effect, whether Rule 5.3.5 solely contributed to the decrease in injury incidence, or both. Follow-up research examining how each rule modification was received by high school boys' lacrosse players and coaches may help to further elucidate the mechanisms behind our results.

At the same time, additional analyses revealed that the rule modifications were not associated with changes in the injury incidence for competition injuries. This is important to note as these rules were modified to affect game play during competitions to protect players. Follow-up studies may help to explain how these rules are enforced during game play. Rather, decreases in the injury incidence were found for practice injuries. It is possible that the rule modifications motivated high school boys' lacrosse programs to alter the content of practice sessions, including the types of contact drills performed. As the result of increasing awareness of concussions being associated with contact, messaging about different concussion-prevention efforts has taken hold and is also having effects on high school sports aside from football. Authors of more in-depth follow-up research could identify whether such changes occurred in practice sessions. Meanwhile, further injury surveillance to assess the long-term effects of these rule modifications is recommended.

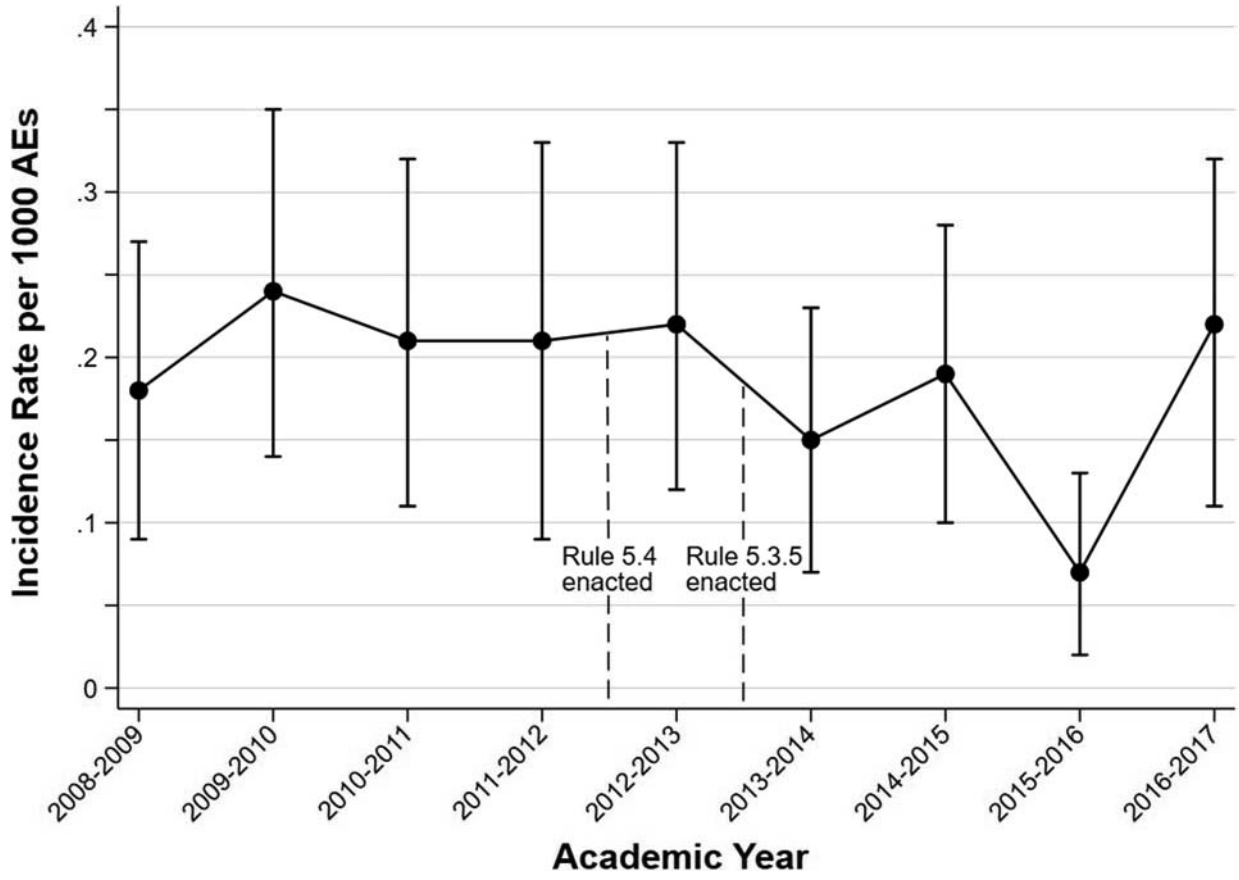

Figure 4. Practice injury rate changes over time after implemented rule modifications. Note: 2008–2009 to 2011–2012 was the time period before both Rule 5.4 (minimizing contact to the head) and Rule 5.3.5 (minimizing injuries due to body checking) modifications. During 2012–2013, Rule 5.4 was enacted, but Rule 5.3.5 was not. During 2013–2014 to 2016–2017, both rules were enacted. Abbreviation: AEs, athlete-exposures.

Injury-Prevention Strategies

The need to examine checking- and contact-related injuries in lacrosse remains integral. Bartley et al[7] identified the head or face as the most injured body part due to intentional contact (checking) in high school boys' lacrosse (42.8%). We similarly found that 40% of injuries resulting from intentional contact were HFN injuries. Marar et al[5] determined that being body checked (18.0%), chasing a loose ball (13.5%), and delivering body checking (12.4%) were the mechanisms most associated with concussions in high school boys' lacrosse. Our results indicated that 76.6% of all HFN injuries were diagnosed as concussions. Furthermore, 45.2% of the overall injuries sustained by those who received body checks were HFN injuries, with 89.4% of those injuries diagnosed as concussions. In addition, 39.2% of the overall injuries sustained by those delivering a body check resulted in a concussion diagnosis. Other head and face injuries reported previously were fractures, contusions, and lacerations.[18] Also, authors[19] who analyzed head impacts using video analysis and helmet sensor data in men's collegiate lacrosse found that high-magnitude head impacts ($>70g$) occurred mostly when the player was delivering a body check (32%). These results emphasize the importance of examining checking mechanisms and HFN injuries in boys' lacrosse.

Although our data suggested decreases in injury incidence associated with Rule 5.4 and 5.3.5 modifications, we were unable to account for other injury-prevention programming that may have been implemented in specific high school boys' lacrosse programs nationwide and in our sample. Moreover, additional strategies to reduce the incidence of injury in high school boys' lacrosse are warranted. The use of protective equipment has been a significant focus for primary prevention of injuries in boys' lacrosse. Helmets protect against lacerations and other head- and face-related injuries but are far less effective in minimizing concussive blows due to impacts with other players.[20,21] However, protective equipment does not always lead to reductions in injury incidence. In men's high school and collegiate lacrosse, an increased incidence of certain injuries, such as shoulder injuries and shoulder instability, was shown in proportion to the amount of protective equipment worn by the player and the severity of the impact.[22,23]

Educational programs targeted at coaches or players, much like the "Heads Up Football" program initiated by USA Football, could continue to be assessed as well. This program arose from the "Heads Up" initiative started by the Centers for Disease Control and Prevention in 2003, which emphasized the importance of concussion awareness among youth and adolescents. Current educational programs used by US Lacrosse include coach-targeted development certification programs,[24] which prioritize the importance of coaches teaching the game to players in an effective manner, and US Lacrosse and Positive Coaching Alliance programs.[25] Studies designed to evaluate the

Table 3. Injury Counts and Rates for All Injuries, HFN Injuries, and Concussions by Type of Checking and Time Period[a] Associated with Rule 5.4 that Aimed to Eliminate Checks to the Head, Face, or Neck

	Checking Delivered				Checking Received					
	Body		Stick		Body		Stick		Total	
Outcome	2008–2009 to 2011–2012	2012–2013	2008–2009 to 2011–2012	2012–2013	2008–2009 to 2011–2012	2012–2013	2008–2009 to 2011–2012	2012–2013	2008–2009 to 2011–2012	2012–2013
Injuries, No.										
Overall	63	19	23	6	89	18	59	17	234	60
HFN	36	11	1	2	36	11	16	6	89	30
Concussion	30	5	1	1	33	9	12	5	76	20
Injury rate/1000 AEs										
Overall	0.15	0.17	0.06	0.05	0.21	0.16	0.14	0.15	0.56	0.53
HFN	0.09	0.10	0.00	0.02	0.09	0.10	0.04	0.05	0.21	0.27
Concussion	0.07	0.04	0.00	0.01	0.08	0.08	0.03	0.04	0.18	0.18
IRR (95% CI)[b]										
Overall	1.12 (0.67, 1.87)		0.97 (0.39, 2.38)		0.75 (0.45, 1.25)		1.07 (0.62, 1.83)		0.95 (0.72, 1.26)	
HFN	1.13 (0.58, 2.23)		7.42 (0.67, 81.83)		1.13 (0.58, 2.23)		1.39 (0.54, 3.56)		1.25 (0.83, 1.89)	
Concussion	0.62 (0.24, 1.59)		3.71 (0.23, 59.32)		1.01 (0.48, 2.11)		1.55 (0.54, 4.39)		0.98 (0.60, 1.60)	

Abbreviations: AEs, athlete-exposures; HFN, head, face, or neck; IRR, injury rate ratio.

[a] The AEs were 416 896 for 2008–2009 to 2011–2012 and 112 372 for 2012–2013.

[b] The IRRs compared the academic years postrule modification (2012–2013) with the academic years prerule modification (2008–2009 to 2011–2012). An IRR $<$ 1 denotes a decrease in the injury rate postrule modification versus prerule modification. An IRR $>$ 1 denoted an increase in the injury rate postrule modification versus prerule modification. The 2013–2014 to 2016–2017 academic years were not considered in the analysis as an additional and related rule modification was enacted during that time period.

effectiveness of these programs may help to identify the levels of reported implementation and suggest opportunities for improving programs and their success rates.[26] We did not gather specific data on how different officials were educated about these rule changes. Yet these changes have been noted in every annual update to the sport's NFHS rule book. Videos, presentations, and written interpretations of the rules are used to supply officials with information, but these methods should be considered as possible areas for analyzing and establishing the best practices to improve officials' recognition and enforcement of new rules.

Limitations

The HS RIO database includes only high schools with National Athletic Trainers' Association–affiliated ATs. Therefore, our results may not be generalizable to high schools without ATs. The findings may also not be generalizable to other lacrosse settings, including those at the youth, collegiate, and professional levels of play. Even with a large dataset, some of the data were limited (eg, for stick checking). The CIs for data involving stick checking and being stick checked were wide due to the small number of events. This further affects the accuracy of the data presented, and more investigation is needed to quantitatively assess the collection of these data in large datasets.

We also could not account for additional factors that may be associated with injury incidence, including those originating from the individual (eg, injury history, playing experience), program (eg, coaching style, content of practice sessions, implementation of other injury-prevention programming), and state (eg, concussion-related legislation). Furthermore, factors unrelated to the rules, such as increased concussion awareness and safety in sports, may have affected the results. Approximately 38% of high school sport coaches exposed to the educational materials were reported to emphasize training techniques and safety equipment that minimized the risk of concussion.[27,28] In a 10-year review of the Centers for Disease Control and Prevention's "Heads Up" initiative, researchers[29] found that health care professionals exposed to this initiative were less likely to clear athletes to return to play the day after concussion. This emphasis on concussion and injury awareness has led to more studies and initiatives to decrease the injury incidence, including programs such as "ACTive: Athletic Concussion Training" and USA Football's "Heads Up Football."

Another limitation was our inability to qualitatively evaluate how officials were implementing these rule modifications in high school lacrosse. The differences in how frequently officials called these penalties in each time period could have affected the results. Additionally, exposures were calculated as AEs, which are event based. The use of exposures that are not time or play based could lead to less accurate results, as different players play variable amounts of time per game or practice. However, it would be extremely difficult for high school ATs to accurately record the minutes of game exposures for all lacrosse athletes. Also, the surveillance system was not primarily designed to evaluate rules changes; it is a convenient medium in which these changes can be evaluated, but the use of a convenience sample did not control for the effect of region or school.

Table 4. Injury Counts and Injury Rates for All Injuries, HFN Injuries, and Concussions by Type of Checking and Time Period[a] Associated with both Rule 5.4 and Rule 5.3.5 Aimed at Eliminating Checks to the HFN and Minimize Body Checks, Respectively

Outcome	Checking Delivered				Checking Received				Total	
	Body		Stick		Body		Stick			
	2008–2009 to 2011–2012	2013–2014 to 2016–2017	2008–2009 to 2011–2012	2013–2014 to 2016–2017	2008–2009 to 2011–2012	2013–2014 to 2016–2017	2008–2009 to 2011–2012	2013–2014 to 2016–2017	2008–2009 to 2011–2012	2013–2014 to 2016–2017
Injuries, No.										
Overall	63	62	23	18	89	79	59	87	234	246
HFN	36	40	1	5	36	40	16	18	89	103
Concussion	30	19	1	3	33	35	12	14	76	71
Injury rate/1000 AEs										
Overall	0.15	0.12	0.06	0.03	0.21	0.15	0.14	0.17	0.56	0.48
HFN	0.09	0.08	0.00	0.01	0.09	0.08	0.04	0.03	0.21	0.20
Concussion	0.07	0.04	0.00	0.01	0.08	0.07	0.03	0.03	0.18	0.14
IRR (95% CI)[b]										
Overall	0.80 (0.56, 1.13)		0.63 (0.34, 1.17)		0.72 (0.53, 0.97)[c]		1.19 (0.86, 1.66)		0.85 (0.71, 1.02)	
HFN	0.90 (0.57, 1.41)		4.04 (0.47, 34.61)		0.90 (0.57, 1.41)		0.91 (0.46, 1.78)		0.94 (0.70, 1.24)	
Concussion	0.51 (0.29, 0.91)[c]		2.43 (0.25, 23.32)		0.86 (0.53, 1.38)		0.94 (0.44, 2.04)		0.76 (0.55, 1.04)	

Abbreviations: AEs, athlete-exposures; HFN, head, face, or neck; IRR, injury rate ratio.

[a] The AEs were 416 896 for 2008–2009 to 2011–2012 and 515 597 for 2013–2014 to 2016–2017.

[b] The IRRs compared the academic years postrule modification (2013–2014 to 2016–2017) with the academic years prerule modification (2008–2009 to 2011–2012). An IRR < 1 denotes a decrease in the injury rate postrule modification versus prerule modification. An IRR > 1 denoted an increase in the injury rate postrule modification versus prerule modification. The 2012–2013 academic year was not considered in the analysis as only 1 rule modification was enacted during that time period.

[c] Indicates significant difference.

CONCLUSIONS

As participation in high school boys' lacrosse continues to grow, so does the concern for increased injury incidence in the sport. The Rule 5.4 modification made checking to the head and face illegal in an attempt to mitigate HFN injuries, whereas the Rule 5.3.5 modification minimized the aggressive use of body checking directed at players in defenseless positions. When both rule modifications were in effect, concussion and overall injury rates decreased for the body checker and the player being body checked, respectively. Still, when practices and competitions were further compared, we found major decreases in certain injury rates during practices and not competitions, although these rule modifications were primarily intended to affect outcomes in competitions. More research is needed to assess how these rules are being enforced, continue evaluating policy or rule modifications, and aid in the development of additional strategies to decrease the injury risk in boys' lacrosse, especially during competitions.

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