Epidemiology of Injuries Sustained as a Result of Intentional Player Contact in High School Football, Ice Hockey, and Lacrosse

2005-2006 Through 2015-2016

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Background: Lacrosse and ice hockey are quickly growing in popularity, while football remains the most popular sport among high school student-athletes. Injuries remain a concern, given the physical nature of these contact sports.

Purpose: To describe the rates and patterns of injuries sustained as a result of intentional player contact in United States high school boys' football, ice hockey, and lacrosse.

Study Design: Descriptive epidemiology study.

Methods: We conducted a secondary analysis of High School RIO (Reporting Information Online) data, including exposure and injury data collected from a large sample of high schools in the United States from 2005-2006 through 2015-2016. Data were analyzed to calculate rates, assess patterns, and evaluate potential risk factors for player-to-player contact injuries.

Results: A total of 34,532 injuries in boys' football, ice hockey, and lacrosse occurred during 9,078,902 athlete-exposures (AEs), for a rate of 3.80 injuries per 1000 AEs in the 3 contact sports of interest. The risk of injuries was found to be greater in competition compared with practice for all 3 sports, with the largest difference in ice hockey (rate ratio, 8.28) and the smallest difference in lacrosse (rate ratio, 3.72). In all 3 contact sports, the most commonly injured body site in competition and practice caused by both tackling/checking and being tackled/checked was the head/face. However, a significantly greater proportion of concussions sustained in football were the result of tackling compared with being tackled (28.2% vs 24.1%, respectively). In addition, a significantly greater proportion of concussions were sustained in competition compared with practice for all 3 sports.

Conclusion: This study is the first to collectively compare injury rates and injury patterns sustained from intentional player-to-player contact in boys' high school football, ice hockey, and lacrosse. Notably, there was a relatively high risk of injuries and concussions during football practices.

Keywords: High School RIO; injury; football; ice hockey; lacrosse

Although the rate of growth of high school athletic participation has slowed, the total number of high school student-athletes continues to rise. According to the National Federation of State High School Associations' annual report, the number of participants in high school athletics reached an all-time high of 7.9 million in the 2015-2016 academic year.[12] Despite widely publicized concerns regarding concussions among football players, the number of boys participating in 11-player football in 2015-2016 was nearly identical to 2014-2015, at 1,083,308.[12] Of all sports, football is the most popular high school boys' program in the United States (US).[12] In addition, the popularity of boys' lacrosse and ice hockey continues to be evident, with 109,522 and 35,155 participants, respectively, in 2015-2016.[12] As the popularity of sports, and thus the number of student-athletes, continues to rise, so will the incidence of injuries. Adolescents are possibly at a greater risk for serious injuries compared with children because of the significant increases in size, strength,

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velocity, and impact force.[5,6,8,10] In addition, when the rules associated with a sport allow and encourage significant contact, which is the case with football, ice hockey, and lacrosse, the risk for player-to-player contact injuries increases.[10]

Player-to-player contact represents 46.4% of all high school sports injuries and thus is the most common mechanism of injury among high school athletes.[8] In 2011, football was reported to have the highest player-to-player contact injury rate, with tackling/being tackled accounting for 61.9% of football injuries.[8] Body checking was the reported mechanism of injury in 46.0% of injuries that occurred during high school ice hockey participation as well as being the most common mechanism of injury in high school lacrosse (40.9%).[11,16] Injuries continue to be a significant concern, given the popularity and intrinsically physical nature of these sports.

Research comparing player-to-player contact injuries among high school sports with varying levels of contact continues to be limited, hindering the development of sport-specific prevention strategies. Although several studies have described contact-related injuries in high school sports, most studies have focused on an individual sport.[3,11,16] A previously published multisport analysis of player-to-player contact injuries utilizing the High School Reporting Information Online (RIO) database included football during the 2005-2009 academic years but not ice hockey or lacrosse.[8] The addition of ice hockey and lacrosse to the High School RIO database in 2008-2009 has now created a unique opportunity to fully evaluate the characteristics and impact of player-to-player contact injuries among high school athletes who participate in these 3 popular full-contact sports.

The purpose of this study was to describe the rates and patterns of injuries sustained as a result of intentional player contact in US high school boys' football, ice hockey, and lacrosse. The specific aims were to (1) calculate overall injury rates caused by intentional player contact by sport, (2) compare injury patterns by the sport-specific type of intentional player contact (ie, tackling vs being tackled in football and checking vs being checked in ice hockey and lacrosse), (3) describe injury patterns by the type of athletic activity (ie, practice vs competition), and (4) describe concussion injuries by the sport-specific type of intentional player contact and type of athletic activity.

METHODS

Data Collection

Data were collected as part of the National High School Sports-Related Injury Surveillance Study using the Internet-based High School RIO database for the academic years 2005-2006 through 2015-2016. High School RIO captures injury and athlete-exposure (AE) information from a large national sample of US high schools. Reports are submitted online weekly by National Athletic Trainers' Association (NATA)–affiliated certified athletic trainers (ATs) with valid email addresses willing to participate in the study. A detailed description of the study has been provided previously.[1,9,13] In brief, the study began during the 2005-2006 academic year, using a nationally representative sample of 100 US high schools, stratified by school population and geographic region into 8 strata. The original sample included 9 sports (including football). Beginning in 2008-2009, High School RIO expanded the list of sports for which data were collected to eventually add 13 sports, including boys' ice hockey and lacrosse. Some sports have such strong regional popularity (ie, boys' ice hockey) that not enough schools offering each sport volunteer to report to fill each of the 8 strata. Therefore, schools not selected for the original sample offering any of the 22 sports (the original 9 or the added 13) were enrolled in a convenience sample, with the goal of enrolling at least 100 schools reporting for each sport. This sampling methodology resulted in a large, nationally diverse convenience sample of US high schools reporting data on injuries sustained by boys' football, ice hockey, and lacrosse players.

Definition of Exposure and Injury

In High School RIO, an AE is defined as 1 athlete participating in 1 school-sanctioned practice or competition in which the athlete was exposed to the possibility of an athletic injury. Reportable injuries are defined as ones that (1) occurred as a result of participation in practice or competition, (2) required medical attention from an AT or physician, and (3) either restricted the athlete's participation in the sport for at least 1 day beyond the date of injury or resulted in any fracture, concussion, dental injury, or heat illness regardless of whether it resulted in a restriction of the student-athlete's participation. For each reported injury, ATs complete a detailed injury report including athlete demographics (ie, age, height, weight), injury information (ie, site, diagnosis, severity), and injury event information (ie, activity, mechanism). Throughout the study period, submitted information could be reviewed and updated by the ATs if necessary.

Statistical Analysis

Data analysis was conducted using SPSS software (v22.0; IBM Corp). In addition to descriptive statistics (ie,

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Ethical approval for this study was obtained from the Nationwide Children's Hospital Institutional Review Board (study No. IRB08-00003).

TABLE 1
Incidence and Rate of Injuries Sustained as a Result of Intentional Player Contact by Sport and Type of Exposure[a]

Sport	No. of Injuries	No. of AEs	Rate/1000 AEs	Rate Ratio[b]	95% CI[c]
Football					
Competition	16,788	1,315,032	12.76	5.51	5.43-5.95
Practice	14,749	6,363,427	2.32		
Total	31,537	7,678,459	4.11		
Ice hockey					
Competition	845	157,882	5.35	8.28	7.74-8.86
Practice	200	309,396	0.65		
Total	1045	467,278	2.24		
Lacrosse					
Competition	1211	285,299	4.25	3.72	3.52-3.94
Practice	739	647,866	1.14		
Total	1950	933,165	2.09		
Overall					
Competition	18,844	1,758,213	10.72	5.00	4.93-5.07
Practice	15,688	7,320,689	2.14		
Total	34,532	9,078,902	3.80		

[a]AE, athlete-exposure.
[b]Practice is the referent group.
[c]Significant at $\alpha = .05$.

frequencies and proportions), rates and rate comparisons were calculated using unweighted case counts from this convenience sample of US schools reporting boys' football, ice hockey, and lacrosse injuries. Injury rates were calculated as the ratio of case counts per 1000 AEs. Subgroup comparisons were made using rate ratios (RRs) and injury proportion ratios (IPRs). RRs and IPRs with 95% CIs not including 1.0 were considered statistically significant. An example of the RR calculation comparing the rate of lacrosse injuries in competition versus practice is as follows:

$$\text{RR} = \frac{(\text{No. of lacrosse injuries sustained in competition}/\text{No. of lacrosse competition AEs})}{(\text{No. of lacrosse injuries sustained in practice}/\text{No. of lacrosse practice AEs})}.$$

An example of the IPR calculation comparing the proportion of injuries from being tackled in football competition versus practice is as follows:

$$\text{IPR} = \frac{(\text{No. of injuries from being tackled during competition}/\text{No. of total injuries during competition})}{(\text{No. of injuries from being tackled during practice}/\text{No. of total injuries during practice})}.$$

RESULTS

A total of 34,532 injuries were sustained as a result of intentional player contact in boys' football, ice hockey, and lacrosse during 9,078,902 AEs, for a rate of 3.80 injuries per 1000 AEs. Of the 3 sports, football had the highest rates of injury overall (4.11), in competition (12.76), and in practice (2.32). The rate of injuries was significantly higher in competition compared to practice for all 3 sports, with the largest difference in ice hockey (RR, 8.28; 95% CI, 7.74-8.86) (Table 1). In football, 46.6% of all injuries were caused by tackling or being tackled, while 41.1% of ice hockey and 15.3% of lacrosse injuries were caused by checking or being checked. For all 3 sports, a significantly greater proportion of injuries resulting from being tackled/checked or tackling/checking occurred during competition compared to practice. Ice hockey had the greatest difference in the proportion of such injuries sustained during competition compared to practice for both checking (IPR, 8.88; 95% CI, 4.58-17.19) and being checked (IPR, 7.54; 95% CI, 5.64-10.07) (Table 2). Football had the lowest difference in the proportion of injuries sustained during competition compared to practice caused by tackling (IPR, 1.48; 95% CI, 1.43-1.53) and being tackled (IPR, 1.88; 95% CI, 1.81-1.94).

Patterns of Injury by Body Site

The most commonly injured body site due to tackling/checking was the head/face for football (29.2%), ice hockey (26.6%), and lacrosse (42.8%) (Table 3). The most commonly injured body site due to being tackled/checked was also the head/face for football (25.1%), ice hockey (37.1%), and lacrosse (47.5%). There were some significant differences in body sites injured by athletes tackling/checking compared to those being tackled/checked. For example, the proportion of head/face injuries was significantly higher for athletes tackling compared to being tackled in football (IPR, 1.17; 95% CI, 1.11-1.23), as was the proportion of neck/cervical spine injuries (IPR, 2.03; 95% CI, 1.71-2.40) and hand/wrist injuries (IPR, 2.15; 95% CI, 1.94-2.39). In lacrosse, the proportion of knee injuries was significantly higher for athletes being checked compared to athletes checking (IPR, 3.45; 95% CI, 1.18-10.07).

Patterns of Injury by Diagnosis

Overall, the most common injury diagnosis due to tackling/checking was a concussion for football (28.2%), ice hockey

TABLE 2
Proportion of Injuries Sustained as a Result of Intentional Player Contact by Type of Contact, Type of Exposure, and Sport[a]

Sport	Total Intentional Player Contact Injuries, %	Intentional Player Contact Injuries[b]			Overall Competition vs Practice	
		Competition, n (%)	Practice, n (%)	Total, n (%)	Injury Proportion Ratio[c]	95% CI[d]
Football						
Tackling	46.8	4098 (59.6)	2776 (40.4)	6874 (100.0)	1.48	1.43-1.53
Tackled	53.2	5103 (65.2)	2720 (34.7)	7823 (100.0)	1.88	1.81-1.94
Total	100.0	9201 (62.6)	5496 (37.4)	14,697 (100.0)	1.67	1.63-1.72
Ice hockey						
Checking	18.4	71 (89.9)	8 (10.1)	79 (100.0)	8.88	4.58-17.19
Checked	81.6	309 (88.3)	41 (11.7)	350 (100.0)	7.54	5.64-10.07
Total	100.0	380 (88.6)	49 (11.4)	429 (100.0)	7.76	5.95-10.12
Lacrosse						
Checking	46.3	103 (74.6)	35 (25.4)	138 (100.0)	2.94	2.16-3.98
Checked	53.7	124 (77.5)	36 (22.5)	160 (100.0)	3.44	2.55-4.65
Total	100.0	227 (76.2)	71 (23.8)	298 (100.0)	3.20	2.59-3.96

[a]Intentional player contact is defined as tackling or being tackled in football and checking or being checked in lacrosse and ice hockey.
[b]Percentage of the total number of injuries for the specific sport (see Table 1). n does not equal n values from Table 1 because of the small number of injury reports with specific questions left unanswered.
[c]Injury proportion ratio for competition versus practice. A value >1 indicates a greater proportion of injuries during competition.
[d]Significant at $\alpha = .05$.

TABLE 3
Proportion of Injuries by Body Part, Diagnosis, Sport, and Type of Contact[a]

	Football		Ice Hockey		Lacrosse	
	Tackling	Tackled	Checking	Checked	Checking	Checked
Body part injured						
Head/face[b]	2008 (29.2)	1962 (25.1)	21 (26.6)	130 (37.1)	59 (42.8)	76 (47.5)
Neck/cervical spine	356 (5.2)	200 (2.6)	2 (2.5)	5 (1.4)	3 (2.2)	3 (1.9)
Shoulder	1228 (17.9)	820 (10.5)	16 (20.3)	72 (20.6)	34 (24.6)	16 (10.0)
Clavicle/collarbone	89 (1.3)	282 (3.6)	9 (11.4)	24 (6.9)	14 (10.1)	11 (6.9)
Hand/wrist	948 (13.8)	501 (6.4)	8 (10.1)	26 (7.4)	10 (7.2)	4 (2.5)
Chest/thoracic spine/ribs	140 (2.0)	268 (3.4)	2 (2.5)	16 (4.6)	4 (2.9)	8 (5.0)
Knee	633 (9.2)	1158 (14.8)	8 (10.1)	16 (4.6)	4 (2.9)	16 (10.0)
Ankle	454 (6.6)	961 (12.3)	2 (2.5)	6 (1.7)	1 (0.7)	7 (4.4)
Other[c]	1013 (14.7)	1668 (21.3)	11 (13.9)	55 (15.7)	9 (6.5)	19 (11.9)
Total	6869 (100.0)	7820 (100.0)	79 (100.0)	350 (100.0)	138 (100.0)	160 (100.0)
Injury diagnosis						
Concussion	1939 (28.2)	1885 (24.1)	16 (20.5)	118 (33.7)	54 (39.1)	70 (43.8)
Contusion	790 (11.5)	1370 (17.5)	12 (15.4)	60 (17.1)	16 (11.6)	24 (15.0)
Ligament sprain	1374 (20.0)	2132 (27.3)	15 (19.2)	48 (13.7)	16 (11.6)	25 (15.6)
Muscle strain	605 (8.8)	494 (6.3)	3 (3.8)	17 (4.9)	9 (6.5)	8 (5.0)
Fracture	773 (11.3)	943 (12.1)	13 (16.7)	46 (13.1)	17 (12.3)	15 (9.4)
Dislocation/separation	467 (6.8)	314 (4.0)	9 (11.5)	25 (7.1)	12 (8.7)	3 (1.9)
Other[d]	916 (13.3)	670 (8.6)	10 (12.8)	36 (10.3)	14 (10.1)	15 (9.4)
Total	6864 (100.0)	7808 (100.0)	78 (100.0)	350 (100.0)	138 (100.0)	160 (100.0)

[a]Values are presented as n (%). n does not equal n values from Tables 1 and 2 because of the small number of injury reports with specific questions left unanswered. Intentional player contact is defined as tackling or being tackled in football and checking or being checked in lacrosse or ice hockey.
[b]Includes mouth, teeth, ears, eyes, and nose injuries.
[c]All body sites that did not make up at least 5% of the total intentional player contact injuries for any individual sport (eg, abdomen, upper arm, and hip).
[d]All diagnoses that did not make up at least 5% of the total diagnoses for any individual sport (eg, abrasion, hernia, and internal injury).

(20.5%), and lacrosse (39.1%) (Table 3). The most common injury diagnosis due to being checked was also a concussion in ice hockey (33.7%) and lacrosse (43.8%). However, in football, the most common injury diagnosis due to being tackled was a ligament sprain (27.3%), with concussion being the second most common (24.1%). There were some

TABLE 4
Proportion of Intentional Player Contact Concussion Injuries by Practice Versus Competition[a]

	Concussion Injuries[b]			Overall Competition vs Practice	
Sport	Competition, n (%)	Practice, n (%)	Total, n (%)	Injury Proportion Ratio[c]	95% CI[d]
Football					
Tackling	1162 (59.9)	777 (40.1)	1939 (100.0)	1.50	1.40-1.60
Tackled	1192 (63.2)	693 (36.8)	1885 (100.0)	1.72	1.60-1.84
Ice hockey					
Checking	16 (100.0)	0 (0.0)	16 (100.0)	—	—
Checked	102 (86.4)	16 (13.6)	118 (100.0)	6.38	4.02-10.11
Lacrosse					
Checking	43 (79.6)	11 (20.4)	54 (100.0)	3.91	2.27-6.74
Checked	55 (78.6)	15 (21.4)	70 (100.0)	3.67	2.30-5.84

[a]Intentional player contact is defined as tackling or being tackled in football and checking or being checked in lacrosse and ice hockey.
[b]n does not equal n values from Tables 1 to 3 because of the small number of injury reports with specific questions left unanswered.
[c]Injury proportion ratio for competition versus practice. A value >1 indicates a greater proportion of injuries during competition.
[d]Significant at $\alpha = .05$.

significant differences in the diagnoses of injuries by athletes tackling/checking compared to those being tackled/checked. In football, the proportion of ligament sprain injuries was significantly higher from being tackled compared to tackling (IPR, 1.36; 95% CI, 1.29-1.45), while the proportion of dislocation/separation injuries was significantly higher from tackling compared to being tackled (IPR, 1.69; 95% CI, 1.47-1.95). In lacrosse, the proportion of dislocation/separation injuries was also higher from checking compared to being checked (IPR, 4.64; 95% CI, 1.34-16.10).

Concussions

Although the difference was small, a significantly greater proportion of concussions sustained in football were the result of tackling (28.2%) compared to being tackled (24.1%) (IPR, 1.17; 95% CI, 1.11-1.24) (Table 3). Conversely, in ice hockey, a greater proportion of concussions were sustained while being checked (33.7%) compared to checking (20.5%) (IPR, 1.64; 95% CI, 1.04-2.61). For all 3 sports, there was a significantly higher proportion of player-to-player contact–related concussions sustained in competition compared to practice; no concussions sustained in ice hockey practice were caused by checking (Table 4). Ice hockey had the greatest proportion of concussions due to being checked during competition compared to practice (IPR, 6.38; 95% CI, 4.02-10.11). On the other hand, football had the lowest proportion of concussions during competition versus practice that were caused by tackling (IPR, 1.50; 95% CI, 1.40-1.60) and being tackled (IPR, 1.72; 95% CI, 1.60-1.84). The majority of concussions occurred during the regular season for football (tackling: 74.9%; being tackled: 77.1%), ice hockey (checking: 100.0%; being checked: 95.8%), and lacrosse (checking: 90.7%; being checked: 90.0%). The proportion of preseason concussions was higher in football (tackling: 21.7%; being tackled: 18.9%) compared to ice hockey (checking: 0.0%; being checked: 3.4%) and lacrosse (checking: 9.3%; being checked: 10.0%).

Patterns of Injury by Severity

The majority of injured football players returned to activity less than 1 week after an injury due to being tackled (37.9%) (Figure 1); however, the majority of football athletes injured by tackling returned to activity within 1 to 3 weeks (37.3%). The majority of ice hockey athletes returned to activity less than 1 week after an injury due to checking (32.9%) or being checked (38.5%). In lacrosse, the majority of players returned to activity in 1 to 3 weeks after an injury sustained by checking (38.1%) or being checked (36.5%). The proportion of injuries that resulted in medical disqualification for the season was higher for athletes being tackled/checked compared to athletes tackling/checking in all 3 sports (football: 7.3%; ice hockey: 5.4%; lacrosse: 7.7%). In football, medical disqualification for the season was significantly higher for athletes being tackled (7.3%) compared to athletes tackling (6.4%) (IPR, 1.14; 95% CI, 1.01-1.29).

For all 3 sports, the percentage of injuries resulting in surgery was small, both when caused by tackling/checking (football: 6.8%; ice hockey: 3.9%; lacrosse: 6.0%) and being tackled/checked (football: 6.3%; ice hockey: 5.5%; lacrosse: 3.8%). There were no significant differences in the need for surgery between athletes tackling/checking versus being tackled/checked.

DISCUSSION

This study is the first to collectively compare injury rates and injury patterns sustained from intentional player-to-player contact in boys' high school football, ice hockey, and lacrosse. Compared with previous epidemiological data, the rate of football injuries from intentional player-to-player contact has increased since 2009: overall (from 2.60/1000 AEs to 4.11), in competition (from 9.00/1000 AEs to 12.76), and in practice (from 1.27/1000 AEs to 2.32).[8] Regarding the mechanism of injury, 46.6% of all football injuries were caused by tackling or being tackled, which is slightly

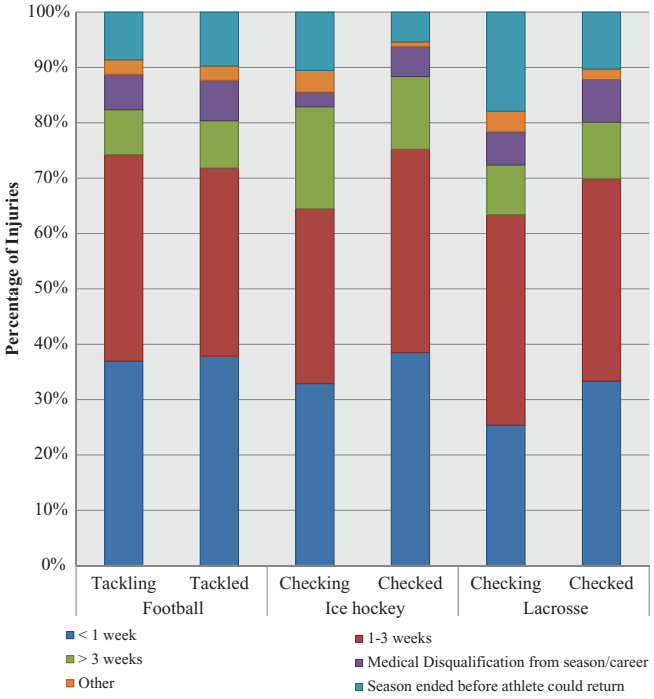

Figure 1. Football, ice hockey, and lacrosse time loss after an injury by type of player-to-player contact. Intentional player contact was defined as tackling or being tackled in football and checking or being checked in lacrosse and ice hockey. <1 week = includes athletes returning to activity in less than 1 day. Other = athlete choosing not to continue, athlete being released from the team, and other.

lower than previously reported (50.1%).[14] In addition, 41.1% of all ice hockey injuries were caused by checking or being checked, which is higher than reported in 2015 (23.4%).[8,11]

Consistent with the previous literature, all 3 sports had overall higher injury rates due to intentional player-to-player contact during competition compared to practice.[3,13,15] This has previously been attributed to generally more aggressive play and more body contact occurring in competition.[16] Although intuitive, this finding has not been collectively reported in the literature previously with all 3 sports within a single study. An interesting finding in this study is that the magnitude of this difference was significantly smaller in football than in ice hockey or lacrosse. Football had the smallest difference in the proportion of player-to-player contact injuries sustained during competition compared to practice, and this was true for both the collective injury rate as well as concussions. In contrast, ice hockey had the largest difference in the proportion of player-to-player contact injuries sustained during competition compared to practice, both collectively as well as for concussions. The difference between the approaches that these 2 sports take during noncompetition and the non–regular season is reiterated by the fact that only 74.9% to 77.1% of total concussions sustained during football occurred during the regular season. In contrast, 100.0% of concussions while checking and 95.8% of concussions while being checked were sustained during the regular season for ice hockey. These collective findings regarding the timing of player-to-player contact injuries imply that ice hockey practices and preseason competitions are relatively safer than football, and it indicates that translating the current approach of ice hockey practices and preseason competitions to football might be a worthwhile preventative measure.

Despite the differences in injury patterns between the sports studied, for all 3, the most commonly injured body site in competition and practice caused by both tackling/checking and being tackled/checked was the head/face. This association between contact sports and head/face injuries affirms the previous study by Kerr et al[8] of player-to-player contact injuries in football, as well as those by Matic et al[11] of hockey and Xiang et al[16] of lacrosse injuries. The head/face is consistently the most commonly injured body site from participation in these 3 contact sports. However, it is interesting to note that in this study, the proportion of head/face injuries, neck/cervical spine injuries, and even concussions was significantly higher for football athletes tackling compared to being tackled, although this may be related to the number of defensive players attempting to tackle a single ball carrier during each play. A difference in checking versus being checked and its relationship to head/face injuries and neck/cervical spine injuries did not reach clinical significance in either lacrosse or ice hockey.

Although this study does not indicate a definitive reason for this finding, it can be inferred that this difference is likely because of the traditional recommended tackling technique taught to high school athletes and the nature of the sport. Typically, high school football players are taught a tackling technique that includes making initial contact with their head and their facemask impacting the opposing player's chest while sustaining a flexed position of the cervical spine to avoid spear-tackling injuries. This approach of leading with the player's head is not recommended or typical during checking an opposing player in ice hockey or lacrosse. In addition, the opposing football player is typically trying to evade being tackled by spinning, cutting, or pivoting, which likely explains the proportion of ligament sprain injuries being significantly higher from being tackled in football. This integral nature of the sport of football and technique taught to student-athletes is likely responsible for not only the significantly higher risk of injuries to the head/face and neck/cervical spine for the player who is tackling but also the significant risk of ligament sprains while being tackled.

The high rate of concussions for all 3 sports is consistent with the recent literature.[4,11,16] In this study, a concussion was the most common injury diagnosis due to tackling/checking in all 3 sports as well as being the most common injury diagnosis due to being checked in ice hockey and lacrosse. Concussions have previously been shown to compose 15.9% of player-to-player contact injuries in high school football.[8] Our reported proportion of concussions sustained in football as the result of tackling (28.2%) and being tackled (24.1%) is higher than previously reported. This difference may be because of published cognitive effects of concussions in National Football League and

collegiate athletes increasing the awareness and vigilance of ATs and medical personnel caring for high school athletes, but it is difficult to speculate further.[2,7]

While this analysis of the High School RIO database offers a novel perspective on rates and patterns of injury in boys' football, ice hockey, and lacrosse as a result of intentional player-to-player contact, addressing certain limitations could improve future studies. First, only high schools with NATA-affiliated ATs were eligible for inclusion in High School RIO. Thus, the findings of this study may not be generalizable to schools without ATs. Another limitation of High School RIO is that except for concussions, fractures, heat illnesses, and dental injuries, only time-loss injuries are captured, which means that the number of injuries reported in this study represents an underestimate. However, limiting the surveillance study to time-loss injuries provides information on clinically important injuries while maintaining a feasible reporting time burden on the high school ATs. Additionally, exposures were captured as numbers of AE instead of hours or minutes of AE, thereby prohibiting us from providing a more exact time-based injury rate. In this large national study, it is not feasible for high school ATs to accurately capture minutes of practice and competition exposures for all athletes in all sports, as they are not present at all activities. We also could not determine sport-specific activity injury rates (ie, the surveillance system does not capture AEs in tackling vs AEs in being tackled), again because of the extreme time burden on reporting ATs. Increased resolution in the information collected from ATs and a larger sample size of injuries would strengthen future analyses of this type. Despite these limitations, the large number of injuries captured by this longstanding national high school sports injury surveillance system provided the ability to evaluate the effect of tackling/checking and being tackled/checked on injury rates and patterns in boys' high school football, ice hockey, and lacrosse for the first time.

CONCLUSION

This study is the first to collectively compare injury rates and injury patterns sustained from intentional player-to-player contact in boys' high school football, ice hockey, and lacrosse. Understanding the rates and patterns of such injuries is particularly important, given the growing concerns regarding the safety of full-contact sports for young athletes. Notably, there was a relatively high risk of injuries and concussions during football practices and preseason activities. Future studies are needed to further investigate these patterns in high school contact athletes, with particular emphasis placed on understanding the lower risk of player-to-player contact injuries and concussions during ice hockey practices/preseason activities and then translating similar approaches to other contact sports.

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