Impact Locations and Concussion Outcomes in High School Football Player-to-Player Collisions

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KEY WORDS
epidemiology, injury surveillance, traumatic brain injury

ABBREVIATIONS

AE—athlete-exposure
AT—athletic trainer
CI—confidence interval
HITS—Head Impact Telemetry System
IPR—injury proportion ratio
RIO—Reporting Information Online
RRs—rate ratios

Dr Kerr helped conceptualize and design the study, led analyses, and drafted the initial manuscript; Mrs Collins helped design the study, assisted with analyses, assisted drafting the initial manuscript, and reviewed and revised the manuscript; Dr Mihalik helped design the study, assisted with analyses, and reviewed and revised the manuscript; Drs Marshall, Guskiewicz, and Comstock helped conceptualize and design the study, assisted with analyses, and reviewed and revised the manuscript; and all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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WHAT'S KNOWN ON THIS SUBJECT: Recent concussion research has examined the role of impact location (ie, the area on the head to which impact occurred); however, no studies exist regarding impact location's association with concussion outcomes (eg, symptomatology, symptom resolution time, return to play).

WHAT THIS STUDY ADDS: This study is the first to examine the association of impact location and concussion outcomes in young athletes. Our findings suggest that impact location, as assessed by sideline observers/player report, is likely of little use in predicting clinical outcomes.

abstract

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BACKGROUND: Little research has examined concussion outcomes in terms of impact location (ie, the area on the head in which the impact occurred). This study describes the epidemiology of concussions resulting from player-to-player collision in high school football by impact location.

METHODS: National High School Sports-Related Injury Surveillance Study data (2008/2009–2012/2013) were analyzed to calculate rates and describe circumstances of football concussion (eg, symptomology, symptom resolution time, return to play) resulting from player-to-player collisions by impact location (ie, front-, back-, side-, and top-of-the-head).

RESULTS: Most concussions resulting from player-to-player collisions occurred from front-of-the-head (44.7%) and side-of-the-head (22.3%) impacts. Number of symptoms reported, prevalence of reported symptoms, symptom resolution time, and length of time to return to play were not associated with impact location. However, a larger proportion of football players sustaining concussions from top-of-the-head impacts experienced loss of consciousness (8.0%) than those sustaining concussions from impacts to other areas of the head (3.5%) (injury proportion ratio 2.3; 95% confidence interval 1.2–4.2; $P = .008$). Players had their head down at the time of impact in a higher proportion of concussions caused by top-of-the-head impacts (86.4%) than concussions from impacts to other areas of the head (24.0%) (injury proportion ratio 3.6; 95% confidence interval 3.2–4.0; $P < .001$).

CONCLUSIONS: Among high school football players who sustained concussions due to player-to-player collisions, concussion outcomes were generally independent of impact location. Recommended strategies for reducing the proportion of top-of-the-head impacts include improved education regarding tackling with proper "head-up" technique. *Pediatrics* 2014;134:489–496

The Centers for Disease Control and Prevention estimates that annually, up to 3.8 million sport-related concussions occur in the United States.[1] For adolescents and young adults, sports, such as football, account for a substantial proportion of concussions.[2] Recent studies estimate the high school football concussion rate at 4.7 to 6.4 per 10 000 athlete-exposures (AEs).[3,4]

Building on past animal model findings,[5–8] recent concussion research has found variations in impact location (ie, the area on the head to which impact occurred).[9,10] However, no studies have examined how symptomatology, symptom resolution time, and length of time until return to play is associated with impact location in youth athletes. This is particularly important because young athletes may be more susceptible to the acute and long-term complications of concussions, compared with older athletes, because of the ongoing neurocognitive development that occurs throughout childhood and adolescence.[11–13] The lack of youth data are concerning because participation in high school athletics is steadily increasing,[14] thus placing more youth at risk for concussion.

A more complete understanding of concussions in high school football is needed to assist clinicians in diagnosing and managing concussed athletes. Such an understanding will help researchers, public health professionals, and policy makers develop evidence-based concussion-prevention interventions. This study describes the epidemiology of concussions sustained from player-to-player collisions in high school football by impact location (ie, the front, back, side, or top of the head). Specific aims included (1) estimate the incidence and rates of concussions by impact location; (2) identify variations in recurrence, symptomatology, symptom resolution time, and return to play associated with impact location; and (3) examine the association between impact location and injury mechanism, head position during injury, and player position.

METHODS

Sample

Data were obtained from the National High School Sports-Related Injury Surveillance System, High School RIO (Reporting Information Online), an Internet-based sports injury surveillance system. The surveillance system, which has been described previously,[15,16] consists of a sample of high schools with 1 or more National Athletic Trainers' Association–affiliated athletic trainers (ATs) with valid E-mail addresses. High School RIO has 2 data collection panels: a random sample of 100 schools recruited annually since 2005/2006 that report data for 9 sports; and an average of 84 schools recruited annually since 2008/2009 that report data for 11 additional sports of interest. For the first panel, high schools were recruited into 8 strata based on school population (enrollment ≤1000, or >1000) and US Census geographic region.[17] If a school dropped out of the system, a replacement from the same stratum is selected. For the second panel, it was impossible to approximate a random sample because of strong regional variations in sport sponsorship. As a result, exposure and injury data for the schools in the second panel represent a convenience sample of US high schools. For this study, we are using data from both panels.

Data Collection

ATs from participating high schools report injury incidence and AE information weekly throughout the academic year by using a secure Web site. For each injury, the AT completed a detailed injury report on the injured athlete (eg, age, height, weight), the injury (eg, site, diagnosis, severity), and the injury event (eg, activity, mechanism). ATs also reported whether injured players had previously sustained concussions (ie, injury recurrence). Throughout the study, participating ATs were able to view and update previously submitted reports as needed with new information (eg, return to play).

Starting in the 2008/2009 school year, ATs reported additional information regarding concussions sustained from player-to-player collisions, including the location of the impact on the athlete's head (categorized as back, front, side, top, or unknown [ie, AT stated that he or she did not know, or AT did not report]) and position of the athlete's head at the time of the impact (categorized as head-up, head-down, no flexion [ie, no bending of the head up or down], other, or unknown). ATs also used a drop-down menu to report symptoms associated with concussion, concussion symptom resolution time, and mechanism of injury. Symptoms used in RIO originate from those used within the National Collegiate Athletic Association Injury Surveillance System.[18]

Injury and Exposure Definitions

An AE was defined as 1 athlete participating in a whole, or any part of, a team athletic practice or competition. An injury in RIO is defined as one that (1) results from participation in a school-sanctioned practice or competition that (2) requires medical attention by an AT or physician, and (3) results in a restriction of the athlete's participation for at least 1 day. Since the 2007/2008 school year, RIO has collected data on any concussion resulting from participation in a school-sanctioned practice or competition high school, regardless of whether it resulted in a restriction of the student-athlete's participation. Thus, the reported concussions included in this study were

(1) reported during the 2008/2009 to 2012/2013 school years, (2) sustained during participation in boys' football, (3) sustained during practice or competition, and (4) caused by player-to-player collisions. We did not provide a definition of concussion, as we relied on the expertise of each medically trained professional who provided concussion data for the High School RIO surveillance system.

Statistical Analysis

We calculated injury rates as the number of concussions per 10 000 AEs, rate ratios (RRs), injury proportion ratios (IPRs), χ^2 tests, and Fisher's exact tests when insufficient sample sizes were present for χ^2 tests.

Competition-to-practice RRs were defined as follows:

$$RR = \frac{\frac{\text{number of competiton concussions}}{\text{number of competition AEs}}}{\frac{\text{number of practice concussions}}{\text{number of practice AEs}}}$$

Competition-to-practice IPRs were defined as follows:

$$IPR = \frac{\frac{\text{number of concussions from impact to top of head resulting in loss of consciousness}}{\text{number of total concussions from impact to top of head}}}{\frac{\text{number of concussions from impact to other areas of the head resulting in loss of consciousness}}{\text{number of total concussions from impact to other areas of head}}}$$

All analyses were conducted with SAS version 9.3 (SAS Institute, Inc, Cary, NC). Level of significance for all analyses was set a priori at $P < .05$. This study was approved by The University of North Carolina at Chapel Hill.

RESULTS

Concussion Incidence and Rates, by Impact Location

ATs reported 2917 football-related concussions during 2008/2009 to 2012/2013. Four concussions occurred outside of practice and competition, 13 concussions had missing information regarding type of exposure (ie, practice/competition/other), and 374 concussions were not caused by contact with another athlete (ie, did not result from player-to-player impact). These 391 cases (13.4%) were excluded from analysis. Of the 2526 concussions included in analysis, 1486 (58.8%) occurred during competition, and 1040 (41.2%) occurred during practice. These concussions occurred during 2 517 207 AEs, for an injury rate of 10.0 concussions from player-to-player collisions per 10 000 AEs (95% confidence interval [CI] 9.6–10.4) (competition = 35.7, 95% CI 33.9–37.5; practice = 5.0, 95% CI 4.7–5.3) (Table 1).

Most concussions caused by player-to-player collisions were from front-of-the-head impacts (44.7%), followed by the side-of-the-head (22.3%), back-of-the-head (5.7%), and top-of-the-head (5.5%) impacts. An additional 551 concussions (21.8%) had an unknown impact location. The rate of concussions resulting from player-to-player collisions was higher in competition than in practice, overall and within specific impact locations (all $P < .001$). The rate of reported football-related concussions caused by player-to-player collisions also increased across the study period (Table 2). The following sections use data only in which the concussions sustained were recorded with a known impact location ($n = 1975$).

Injury Recurrence

Among all concussions from a player-to-player impact, 9.6% were reported to be recurrent rather than new concussions (Table 3). Of these 190 concussions, 23.1% of the recurrent concussions had occurred within the same academic year. Injury recurrence was not associated with impact location ($P = .80$).

Symptomatology

On average, athletes concussed from a player-to-player impact reported 4.6 ± 2.3 symptoms. The number of symptoms was not associated with impact location (Fig 1, $P = .67$). However, players with recurrent concussion sustained from side-of-the-head and top-of-the-head impacts reported more average number of symptoms compared with players with new concussions (side-of-the-head: 5.5 vs 4.6, $P = .004$; top-of-the-head: 6.9 vs 4.4, $P = .004$; Table 3).

TABLE 1 Concussion Counts (and Percentages) and Rates[a] (and 95% CIs) Among US High School Athletes, by Impact Direction, High School Sports-Related Injury Surveillance Study, United States, 2008/2009 to 2012/2013

Type of Exposure	Impact Location					Total
	Back	Front	Side	Top	Unknown[b]	
Practice						
n (%)	52 (6.3)	489 (58.9)	231 (27.8)	58 (7.0)	332 (27.6)	1040 (100.0)
Rate (95% CI)	0.2 (0.2–0.3)	2.3 (2.1–2.5)	1.1 (1.0–1.2)	0.3 (0.2–0.3)	1.0 (0.9–1.1)	5.0 (4.7–5.3)
Competition						
n (%)	91 (7.9)	641 (56.0)	333 (29.1)	80 (7.0)	507 (29.9)	1486 (100.0)
Rate (95% CI)	2.2 (1.7–2.6)	15.4 (14.2–16.6)	8.0 (7.1–8.9)	1.9 (1.5–2.3)	8.2 (7.3–9.1)	35.7 (33.9–37.5)
Total						
n (%)	143 (5.7)	1130 (44.7)	564 (220.3)	138 (5.5)	551 (21.8)	2526 (100.0)
Rate (95% CI)	0.6 (0.5–0.7)	4.5 (4.2–4.8)	2.2 (2.1–2.4)	0.5 (0.5–0.6)	2.2 (2.0–2.4)	10.0 (9.6–10.4)

[a] Rates per 10 000 AEs.

[b] AT stated that he or she did not know impact location, or AT did not report impact location (ie, missing).

TABLE 2 Annual Concussion Counts and Rates[a] (and 95% CIs) Among US High School Athletes, by Impact Direction, High School Sports-Related Injury Surveillance Study, United States, 2008/2009 to 2012/2013

School Year	Impact Location					Total
	Back	Front	Side	Top	Unknown[b]	
2008/2009						
n (%)	21 (5.9)	146 (41.0)	68 (19.1)	21 (5.9)	100 (28.1)	356 (100.0)
Rate (95% CI)	0.4 (0.2–0.5)	2.5 (2.1–2.9)	1.2 (0.9–1.4)	0.4 (0.2–0.5)	1.7 (1.4–2.0)	6.1 (5.4–6.7)
2009/2010						
n (%)	22 (4.9)	189 (42.5)	106 (23.8)	29 (6.5)	99 (22.3)	445 (100.0)
Rate (95% CI)	0.5 (0.3–0.7)	4.0 (3.4–4.5)	2.2 (1.8–2.7)	0.6 (0.4–0.8)	2.1 (1.7–2.5)	7.5 (6.7–8.3)
2010/2011						
n (%)	35 (7.5)	219 (47.0)	97 (20.8)	19 (4.1)	96 (20.6)	466 (100.0)
Rate (95% CI)	0.7 (0.5–1.0)	4.6 (4.0–5.2)	2.0 (1.6–2.5)	0.4 (0.2–0.6)	2.0 (1.6–2.4)	7.5 (6.7–8.3)
2011/2012						
n (%)	26 (5.1)	235 (46.3)	114 (22.4)	33 (6.5)	100 (19.7)	508 (100.0)
Rate (95% CI)	0.6 (0.3–0.8)	5.0 (4.4–5.6)	2.4 (2.0–2.9)	0.7 (0.5–0.9)	2.1 (1.7–2.5)	8.4 (7.6–9.2)
2012/2013						
n (%)	39 (5.2)	341 (45.4)	179 (23.8)	36 (4.8)	156 (20.8)	751 (100.0)
Rate (95% CI)	0.8 (0.5–1.0)	6.7 (6.0–7.4)	3.5 (3.0–4.0)	0.7 (0.5–0.9)	3.1 (2.6–3.5)	9.2 (8.3–10.1)
Total						
n (%)	143 (5.7)	1130 (44.7)	564 (22.3)	138 (5.5)	551 (21.8)	2526 (100.0)
Rate (95% CI)	0.6 (0.5–0.7)	4.5 (4.2–4.8)	2.2 (2.1–2.4)	0.5 (0.5–0.6)	2.2 (2.0–2.4)	10.0 (9.6–10.4)

[a] Rates per 10 000 AEs.
[b] AT stated that he or she did not know impact location, or AT did not report impact location (ie, missing).

Commonly reported symptoms included headache (93.4%), dizziness/unsteadiness (75.9%), difficulty concentrating (61.4%), and confusion/disorientation (51.7%). No single symptom was associated with impact location, except for loss of consciousness (Fig 2). More football players sustaining top-of-the-head impact concussions experienced loss of consciousness (8.0%) than football players sustaining concussions from impacts to all other areas of the head (3.5%) (IPR 2.3; 95% CI 1.2–4.2; $P = .008$).

Symptom Resolution Time and Return to Play

Symptom resolution time for concussions caused by player-to-player collisions ranged from <1 day (21.8%) to ≥1 week (29.0%). Symptom resolution time was not associated with impact location ($P = .71$). However, players with recurrent concussions had a longer symptom resolution time than players with new concussions ($P < .001$).

Most concussed players returned to play within 3 weeks from the date of injury (77.3%). Length of time until return to play was not associated with impact location ($P = .80$); however, players with recurrent concussions had a longer length of time until return to play than players with new concussions ($P = .002$).

Mechanism and Head Position

Overall, most concussions caused by player-to-player collisions were caused by head-to-head contact (70.7%), followed by contact with another player's body site (eg, elbow, knee, foot) (23.0%) and contact with the playing surface (after player-player contact) (6.3%). The proportion of concussions caused by contact with the playing surface was greater among concussions resulting from back-of-the-head impacts (39.1%) than concussions from impacts to other areas of the head (3.8%) (IPR 10.3; 95% CI 7.5–14.0; $P < .001$).

Among the concussions with information regarding head position during contact (81.0%), most occurred with the player in a head-up position (63.3%); an additional 28.9% occurred with the player in a head-down position. Players had their head down at the time of impact in a higher proportion of concussions caused by top-of-the-head impacts (86.4%) than concussions from impacts to other areas of the head (24.0%) (IPR 3.6; 95% CI 3.2–4.0; $P < .001$).

TABLE 3 Concussion Counts and Average Number of Reported Symptoms Among US High School Athletes, by Impact Location and Injury Recurrence, High School Sports-Related Injury Surveillance Study, United States, 2008/2009 to 2012/2013

Impact Location	Recurrent Concussion?	*n* (% Within Impact Location)	Average No. Symptoms (SD)	*P* Value[a]
Back	No	130 (91.5)	4.4 (2.4)	.91
Back	Yes	12 (8.5)	4.3 (2.2)	
Front	No	995 (89.8)	4.6 (2.3)	.30
Front	Yes	113 (10.2)	4.9 (2.5)	
Side	No	503 (90.3)	4.6 (2.3)	.004
Side	Yes	54 (9.7)	5.5 (2.3)	
Top	No	127 (92.0)	4.4 (2.2)	.03
Top	Yes	11 (8.0)	6.9 (3.3)	
Total	No	1755 (90.2)	4.6 (2.3)	.004
Total	Yes	190 (9.8)	5.1 (2.5)	

Does not include 30 concussions without information on injury recurrence.
[a] *P* value are from independent-sample *t* tests comparing average number of reported symptoms between recurrent concussions and new concussions.

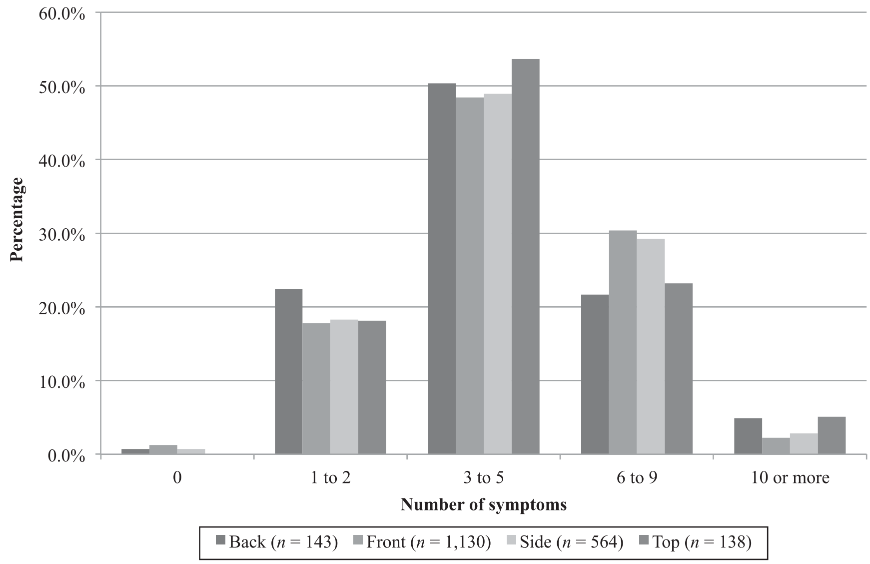

FIGURE 1
Number of symptoms experienced by concussed US high school athletes, by direction of impact, High School Sports-Related Injury Surveillance Study, United States, 2008/2009 to 2012/2013.

Most player-to-player concussions occurred from tackling (35.8%) or being tackled (28.3%), followed by blocking (18.7%) and being blocked (13.6%). Compared with side-of-the-head and back-of-the-head impact concussions (34.7%), a larger proportion of top-of-the-head and front-of-the-head impact concussions were a result of tackling (50.4%) (IPR 1.5; 95% CI 1.2–1.7; $P <$ .001). Of these concussions to the top of head caused by tackling, 76.8% occurred with the player in a heads-down position at impact.

Playing Position

Concussions resulting from player-to-player collisions were most frequently sustained by linebackers (17.0%), running backs (15.2%), and defensive tackles (9.5%). The proportion of defensive tackles sustaining concussions from top-of-the-head impacts (16.9%) was 1.8 times the proportion of defensive tackles sustaining concussions from impacts to all other areas of the head (9.3%) (95% CI 1.2–2.7; $P = .01$). Of these top-of-the-head impact concussions sustained by defensive tackles, 68.8% occurred with the player in a head-down position, and 53.3% were from head-to-head contact. The proportion of quarterbacks sustaining concussions from back-of-the-head impacts (7.1%) was 2.4 times the proportion of quarterbacks sustaining concussions from impacts to all other areas of the head (3.0%) (95% CI 1.2–4.6; $P = .03$).

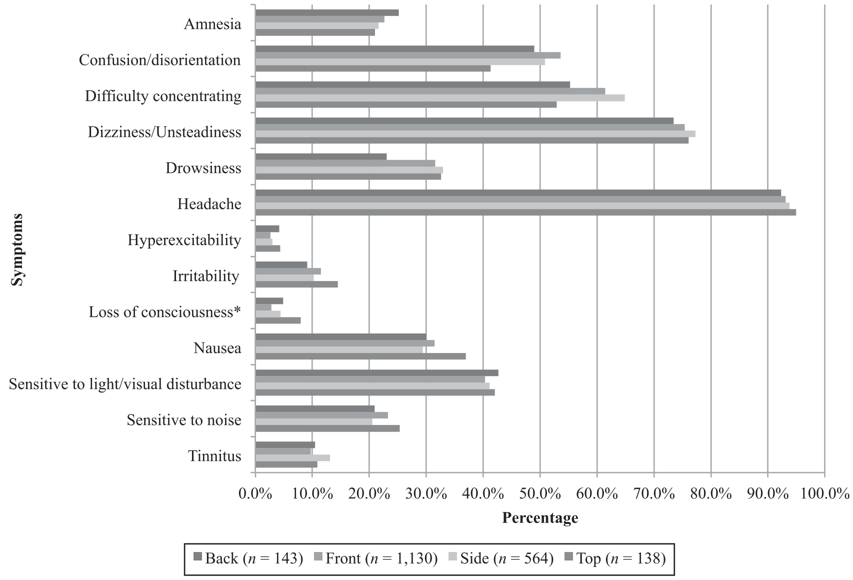

FIGURE 2
Proportion of concussed US high school football athletes reporting symptoms, by direction of impact, High School Sports-Related Injury Surveillance Study, United States, 2008/2009 to 2012/2013. *$P = .001$.

DISCUSSION

Among high school football players who sustained concussions from player-to-player collisions, the number of symptoms reported, prevalence of symptoms, symptom resolution time, and length of time to return to play were generally independent of impact location. Alongside previous findings that clinical measures of acute symptom severity, postural stability, and neuropsychological function were independent of impact location,[9] our findings suggest that impact location is likely of little use in predicting clinical outcomes, and helping clinicians manage concussed players. Because not all high schools have access to ATs,[19] concussed athletes without AT access may present to their pediatricians, who should be well-informed of up-to-date concussion-related information.

One such piece of concussion-related information is players' previous concussion histories. As seen in previous research,[20] injury recurrence was associated with a larger number of reported symptoms, a longer length of time to return to play, and a longer symptom resolution. Consequently, previous concussion history may have more clinical value than impact location.

A limitation of these data are that they only include impacts resulting in injury. We have no data regarding the distribution of impact location for player-to-player collisions that did not result in concussion. Despite this limitation, our findings indicated that a larger proportion of football players concussed from player-to-player top-of-the-head impacts sustained loss of consciousness compared with those concussed from player-to-player collision impact to other areas of the head. In high school athletes, top-of-the-head impacts may have larger linear magnitude accelerations than impacts sustained elsewhere.[21] No association reportedly exists between impact location and magnitude of impact acceleration in a small collegiate sample (n = 13).[9] This may be because of differences between collegiate and high school play, or methodological differences in how "top of the head" is defined. At the same time, when considering injury recurrence and impact location simultaneously, we found that players with recurrent concussion sustained from side-of-the-head and top-of-the-head impacts reported a larger average number of symptoms compared with players without a concussion history. However, this was not found with concussions sustained from front-of-the-head and back-of-the-head impacts. Further understanding the relationship among impact location, injury recurrence, and concussion symptomatology among various playing levels is warranted.

Compared with concussions from impact to other areas of the head, more top-of-the-head impact concussions were sustained while players were head-down at impact and tackling. Tackling head-down places players at risk for permanent paralysis or death from spinal cord injuries as well as from brain injury.[22] Concussions from top-of-the-head impacts, and the resulting risks associated with such impacts, may be reduced by enforcing rules prohibiting players from leading with their head and educating players about tackling using proper "head-up" techniques. Players must never initiate contact with the helmet, or make contact while head-down.[22] In addition, it may be beneficial to revisit the "no-spearing" rules of the late 1970s, which led to a significant reduction in catastrophic cervical spine and brain injuries in the subsequent decades.[23,24]

Our findings are partially consistent with previous research related to concussions by impact location.[9,25] We found that most concussions were from front-of-the-head impacts, which echoes reports from researchers using the Head Impact Telemetry System (HITS) (Simbex, Lebanon, NH), which used accelerometer data to compute peak head and rotational acceleration from impact data in real-time.[21,25] However, a recent study of professional football players found most concussions were from side-of-the-head impacts (K.M.G., unpublished data). In addition, Guskiewicz et al.[9] found that 7 of 13 concussions in their study were from top-of-the-head impacts, and Pellman et al.[10] found 71% of concussions were from back-of-the-head and side-of-the-head impacts.

This study demonstrates that injury surveillance systems can be used to collect data on impact location; however, we caution that the validity and reliably of these data remain unknown. Differences across studies may be attributable to how various studies capture impact and injury data (eg, real-time HITS data, athlete self-report, AT-reported). Numerous studies have used HITS data.[9,21,25] But at a cost of ~\$1500 per helmet in addition to the costs of the data collection system, this is beyond the resources of the vast majority of high schools. Additionally, HITS can currently be used only in helmeted sports, excluding nonhelmet sports in which concussions also occur.[3,4] Furthermore, HITS defines a top-of-head impact as above the 65 degrees of elevation, which is a very large conic section within the overall three-dimensional measurement sphere used by these biomechanical devices. We do not know how this compares with the conic sections that our participating ATs would consider to be "top-of-the-head," or if "top-of-the-head" can be reliably and consistently defined among participating ATs. Thus, identifying cost-effective methods of reporting head impact locations associated with concussions is warranted.

Further evidence supporting the need to develop more cost-effective methods of identifying head impact locations comes from findings in Pellman et al.[10] This study[10] used video coverage to analyze concussive impacts, but these researchers were able to categorize only 31 (17.0%) of 182 observed impacts that occurred on an open field and had footage from 2 unobstructed views. A recent study of professional football players using similar methodology could identify only 145 (45.0%) of 322 observed impacts (K.M.G., unpublished data). Our study relied on the reports of ATs, who relied on the reports of injured players, coaches, or teammates for those injury events they did not witness. Although all schools in the study sample had an AT, 1 AT cannot be present at all sports' practices and competitions in the high school setting. This may explain why a number of concussions that occurred from player-player contact during football practice or competition had missing data related to area of impact (n = 551, 21.8%) and were subsequently excluded from our analysis. However, this study sample represents the largest sample of high school football concussions used to evaluate the association between impact location and the epidemiology of concussion to date.

Strengths and Limitations

Our sample was limited to high schools with ATs. Although the High School RIO Surveillance System captured symptomatology data related to sustaining concussions, numerous symptoms (ie, sadness, trouble falling asleep, feeling like one is "in a fog," and feeling "slowed down") included in other symptom lists (Graded Symptom Checklist, Acute Concussion Evaluation, and Post Concussion Symptom Scale) were not listed options in this surveillance system (although ATs can type in additional symptoms not provided in the drop-down menu). However, RIO relied on medically trained professionals to document injuries, which results in higher-quality data than studies that relied on coach reporting or player self-report.[26] Although a lack of consistency in assessing and diagnosing concussions among various providers may exist, during the High School RIO study period, there was a consistent definition of sports concussion accepted and widely publicized by an international group of experts through periodic Consensus Statements on Concussion in Sport.[27] Furthermore, ATs receive up-to-date and specific education regarding diagnosis of sports-related concussions. Also, concussions occur in multiple high school sports, and rates and patterns of concussion vary by sport, gender, and type of exposure.[4] Future research related to concussion impact location should extend beyond football. Finally, only concussions caused by player-to-player collisions during participation in high school football were considered; 374 concussions sustained by mechanisms other than player-to-player collision were excluded. During the 2008/2009 through 2011/2012 academic years, data used in this study were collected only for concussions caused by player-to-player collisions. However, in 2012/2013, RIO started to collect similar data for concussions sustained by other mechanisms of injury. Despite these limitations, this study is the largest epidemiologic study to date describing concussion stratified by impact location in football players.

CONCLUSIONS

As high school sport participation continues to increase,[14] public health practitioners must identify risk factors and prevention strategies to curb increases in the incidence of concussion. Our findings suggest that among concussions sustained due to impacts to different areas of the head during player-to-player collisions in high school football, few differences exist among the symptomatology, resolution time of symptoms, and time until return to play. However, because a large number of concussions (n = 551) were missing information on impact location, we recommend investigating protocols that will acquire valid and reliable measures of head impact locations that are not cost restrictive. Although using AT reports is a cheaper and less labor-intensive alternative for researchers, the validity and reliably of capturing impact location of such data are unknown. Future research that compares AT reporting with other methods, such as HITS or video replay, will help to establish concurrent validity. In addition, continued surveillance research also will help determine whether our findings are generalizable to other populations and are affected by continued efforts to increase the safety and health of high school football players. Last, we support the prevention strategies recommended by previous research, including better enforcement of rules limiting initiating contact with the head, education regarding the safest way to engage in contact, consistent use of properly fitted protective equipment, and development of better protective equipment.[4,28,29]

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