Effect of a New Rule Limiting Full Contact Practice on the Incidence of Sport-Related Concussion in High School Football Players

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Background: Sport-related concussion (SRC) has been associated with cognitive impairment, depression, and chronic traumatic encephalopathy. American football is the most popular sport among males in the United States and has one of the highest concussion rates among high school sports. Measured head impacts and concussions are approximately 4 times more common in contact practices compared with noncontact practices. The Wisconsin Interscholastic Athletic Association passed new rules defining and limiting contact during practice before the 2014 football season.

Purpose: To determine if the SRC rate is lower after a rule change that limited the amount and duration of full-contact activities during high school football practice sessions.

Study Design: Cohort study; Level of evidence, 2.

Methods: A total of 2081 high school football athletes enrolled and participated in the study in 2012-2013 (before the rule change), and 945 players participated in the study in 2014 (after the rule change). Players self-reported previous concussion and demographic information. Athletic trainers recorded athlete exposures (AEs), concussion incidence, and days lost for each SRC. Chi-square tests were used to compare the incidence of SRC in prerule 2012-2013 seasons with the incidence in the postrule 2014 season. Wilcoxon rank sum tests were used to determine differences in days lost because of SRC.

Results: A total of 67 players (7.1%) sustained 70 SRCs in 2014. The overall rate of SRC per 1000 AEs was 1.28 in 2014 as compared with 1.58 in 2012-2013 ($P = .139$). The rate of SRC sustained overall in practice was significantly lower ($P = .003$) after the rule change in 2014 (15 SRCs, 0.33 per 1000 AEs) as compared with prerule 2012-2013 (86 SRCs, 0.76 per 1000 AEs). There was no difference ($P = .999$) in the rate of SRC sustained in games before (5.81 per 1000 AEs) and after (5.74 per 1000 AEs) the rule change. There was no difference ($P = .967$) in days lost from SRC before (13 days lost [interquartile range, 10-18]) and after (14 days lost [interquartile range, 10-16]) the rule change.

Conclusion: The rate of SRC sustained in high school football practice decreased by 57% after a rule change limiting the amount and duration of full-contact activities, with no change in competition concussion rate. Limitations on contact during high school football practice may be one effective measure to reduce the incidence of SRC.

Keywords: concussion; head injury; football; epidemiology; injury prevention; pediatric sports medicine

Sport-related concussion (SRC) is a concern in the United States, with estimates of anywhere between 300,000 to 3.8 million sport- and recreation-related concussions each year.[11,22] In a national study of 20 popular high school sports in the United States, American football had the highest rate of diagnosed concussion,[12] and in a systematic review and meta-analysis of youth sports, it had the third-highest rate of concussion, behind rugby and hockey.[17] With 1,036,842 participants in the 2017-2018 school year, American football has the most participants for males in high schools in the United States, but the number of athletes participating in high school football has decreased every year since the 2013-2014 school year.[16] Among the reasons why participation in football has declined is concern about the risk of head injuries, potential risks of second-impact syndrome,[15] and chronic traumatic encephalopathy (CTE).[14] Concussion

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has been linked with cognitive impairment[7] as well as depression[8] in retired professional football players. In part because of the risk of head injury and concerns over long-term health, public opinion of playing the sport of football has changed in recent years. In a recent survey, 46% of people stated they would not let their hypothetical 10-year-old son play American football.[23] Conversely, participation in sports has shown benefits in movement skills, physical competencies, social skills, social behaviors, self-esteem, pro-school attitudes, academic development, and cognitive development.[2]

Earlier epidemiological studies showed concussion rates in high school football ranging from 3.66%[18] to 5.6%[9] and an estimated incidence of 43,200 to 67,200 concussions annually.[4] More recent estimates of concussion rates are 9.98% in 2012 and 4.5% in 2013.[6] The National Federation of High Schools estimates that 1.09 million high school athletes participated in high school football in both 2012 and 2013,[16] which corresponds to an estimated incidence between 49,000 and 109,000 concussions in high school football annually. While concussions are 3 to 11 times more likely to occur during games than practice,[6,9,18] concussions occurring in practice accounted for 41% to 58% of total concussions, owing to the greater number of practices than games.[6,13] In addition, measured head impacts $>14.4g$ were 4.3 times more common in contact practice than in noncontact practice,[3] and concussion was shown to be 4 times more likely in full-contact practice than in noncontact practice.[13] After implementation of a rule in Michigan limiting contact practices to 2 times per week after the first game, measured head impacts in practice decreased by 42%.[5]

Given the volume of concussions in football and the potential short- and long-term effects, many proposals have been made to decrease head impact exposure and concussion risk. As a result of research showing more head impacts and concussions in contact practices than in non-contact practices, the Wisconsin Interscholastic Athletic Association (WIAA) passed new rules defining and limiting contact during practice[25] for the 2014 season in an attempt to decrease head impact exposure and concussions. Under the new rules, competition/full contact was not allowed in the first week and was limited to 75 minutes in week 2 (excluding a scrimmage) and to 60 minutes per week (excluding games) in week 3 and beyond. Full contact was defined as full speed with contact where collisions do not have a predetermined winner. Full details of the WIAA rule change are provided in the Appendix (available in the online version of this article). The primary aim of this study was to compare practice, game, and total concussion rates from the 2 seasons before the rule change to the season after the rule change. Secondary analysis included time lost from competition because of SRC.

METHODS

The study was approved by the University of Wisconsin–Health Sciences Institutional Review Board. Before the start of the study, instructions for player recruitment, enrollment, and data collection were provided to ensure that all the athletic trainers (ATs) at participating schools used standardized data collection and reporting methods. All ATs had to undergo institutional research training and certification before taking part in any research-related activities. All subjects (and their parents, if <18 years old) were required to sign a subject consent/assent document to participate.

Data were collected in a convenience sample of high schools in Wisconsin during the 2012 season (34 schools), 2013 (18 schools) season, and 2014 (26 schools) season. Methods for the data collection for the 2012 and 2013 seasons were described previously.[13] To be included in the study, each player had to be on the roster of one of the school's interscholastic football teams (freshman, junior varsity, or varsity) and able to fully participate (no disabling injuries) in team activities on the first day of practice.

Data Collection

Before the start of the season, demographic information was collected from each player by paper-and-pencil survey regarding grade in school, level of competition (freshman, junior varsity, or varsity), expected offensive and defensive playing positions, number of years playing full-contact tackle football, and history of SRC that the subject and parents could recall. In line with previous studies, ATs at each school administered the Concussion Symptom Inventory[21] to measure baseline concussion symptoms before the start of the season.

During the season, the ATs and coaches kept daily attendance logs to record all football-related practice and competition exposures. Practice exposures were classified as being full contact, drill contact, or no contact. Full contact was defined as live competition or full speed with contact, with no predetermined winner. Drill contact can be up to full speed until contact, with contact being above the waist, and the players do not get taken to the ground. No contact has players running unopposed. A practice was defined as full contact if any part included full contact. A practice was defined as drill contact if it included drill contact but not full contact. A practice was defined as no contact if there was no full contact or drill contact.

Definition of SRC

An SRC was defined according to the American Academy of Neurology guideline for diagnosis and management of SRC as "an injury resulting from a blow to the head or other applied forces (linear or rotational) causing an alteration in mental status and 1 or more of the following symptoms: headache, nausea, vomiting, dizziness/balance problems, fatigue, difficulty sleeping, drowsiness, sensitivity to light/noise, blurred vision, memory difficulty, and difficulty concentrating."[19] We employed this definition as part of other clinical research studies being conducted concurrent with this study.

Assessment of SRC

Wisconsin state law requires that any athlete suspected of sustaining an SRC be removed from practice or competition

TABLE 1
Athlete Demographics and Concussion History[a]

	2012-2013[b]		2014[b]		*P* Value
Player-seasons, n	2287		945		
Age, y	15.9 ± 1.2		15.9 ± 1.2		.538
Height, in	70.3 ± 3.2		70.2 ± 3.3		.65
Weight, lb	172.2 ± 36.3		172.9 ± 36.7		.452
BMI, lb/in^2	24.3 ± 4.4		24.3 ± 4.4		.474
Baseline CSI symptom score	1.0 ± 1.2		1.4 ± 2.7		.026
	n	%	n	%	
Grade in school					.834
9	625	27.3	268	28.3	
10	598	26.1	242	25.6	
11	544	23.8	215	22.7	
12	512	22.4	220	23.2	
Competition level					.088
Freshman	567	24.8	200	21.2	
Junior varsity	627	27.2	273	28.9	
Varsity	1093	47.8	472	49.9	
Previous SRC (within 12 mo)					.322
No	2028	88.7	850	89.9	
Yes	259	11.3	95	10.1	
Previous SRC (ever)					.053
No	1849	80.8	792	83.8	
Yes	438	19.2	153	16.2	

[a]BMI, body mass index; CSI, Concussion Symptom Inventory; SRC, sport-related concussion.
[b]Values are presented as mean ± SD unless noted otherwise.

immediately and not be allowed to return to sport activities until examined and cleared by a credentialed medical professional (physician or licensed AT).[1] If an athlete in this study was suspected to have sustained an SRC, the athlete was removed from practice or competition and evaluated by the AT. ATs administered the Concussion Symptom Inventory and used clinical judgment in conjunction with the definition of SRC provided in the study to determine whether the athlete sustained a concussion. In some cases, ATs referred on to additional providers to determine whether an athlete sustained a concussion, or athletes sought care from a different provider before seeing their AT. Additional data were recorded for each SRC, including the type of exposure and the days lost from sport.

Each player with an SRC was allowed to return to football activities only under the direct supervision of the school AT and/or primary care provider (physician), using a statewide mandated stepwise protocol with provisions for delayed return to play based on the return of any signs or symptoms (WIAA concussion policy). Number of days lost from concussion was determined by summing the days lost from the first day after injury until the player returned to unrestricted football practice and/or competition.

Data Analyses

Chi-square tests were used to compare incidence of SRC in prerule 2012-2013 seasons with incidence in postrule 2014 season. Wilcoxon rank sum tests were used to determine differences in days lost from SRC. Analysis was conducted at a significance level of 0.05 and completed with R (v 3.3.1)[20] for statistical computing.

RESULTS

Full data from the 2012 and 2013 football seasons were previously published.[13] Briefly, the overall concussion rate was 8.7% in 2012 and 9.4% in 2013. Demographic information for the participants is provided in Table 1.

There was no difference between subjects enrolled before the rule change and after the rule change for age, grade, previous experience, and previous concussion history. The athletes in the 2014 season did have significantly greater baseline concussion symptom scores than the athletes in the 2012-2013 seasons (P = .026). Table 2 shows the comparison of concussion rates in 2012-2013 (before the rule change) to 2014 (after the rule change).

During the 2014 high school football season, 945 subjects from 26 schools enrolled in the study, resulting in 54,745 athlete exposures (AEs). A total of 67 players (7.1%) sustained 70 concussions (1.28 concussions per 1000 AEs). Concussion incidence was significantly greater in practice during the 2012-2013 seasons (0.76 per 1000 AEs), before the WIAA rule change, than during the 2014 season (0.33 per 1000 AEs), after the rule change (P = .003). In full-contact practice in 2014, the rate of concussion was 0.57 per 1000 AEs as compared with 0.87 per

TABLE 2
Comparison of Concussion Rates Before (2012-2013) and After (2014) Rule Change[a]

2012-2013 Seasons	Exposures	SRCs	SRC Rate[b]	*P* Value	2014 Season	Exposures	SRCs	SRC Rate[b]	*P* Value	*P* Value Between Cohorts
Overall	134,437	211	1.58		Overall	54,745	70	1.28		.139
Session				<.001	Session				<.001	
Practice	112,912	86	0.76		Practice	45,160	15	0.33	<.001	.003
With contact	94,022	82	0.87		Full	20,952	12	0.57		.216[c]
					Drill	10,580	1	0.09		
No contact	18,890	4	0.21		No contact	13,628	2	0.15		
Competition	21,525	125	5.81		Competition	9,585	55	5.74		.999

[a]SRC, sport-related concussion.
[b]Per 1000 athlete exposures.
[c]Full contact in 2014 vs with contact in 2012-2013.

1000 AEs in contact practices in 2012-2013 ($P = .216$). The concussion rate in full-contact practice in 2014 was significantly higher than in drill or noncontact practice ($P < .001$). The competition concussion rate was not changed (5.74 per 1000 AEs in 2014 and 5.81 per 1000 AEs in 2012-2013, $P = .999$), and there was no statistically significant change in the overall rate of concussion (1.28 per 1000 AEs in 2014 vs 1.58 per 1000 AEs in 2012-2013, $P = .139$). There was no difference in concussion rate by previous football experience. Secondary analysis found no difference in days lost because of injury (14 [interquartile range, 10-16] in 2014 and 13 [interquartile range, 10-18] in 2012-2013, $P = .967$).

DISCUSSION

The risk of head injury in football is concerning, and strategies to reduce head injury and head impact exposure are imperative. The WIAA initiated a rule change that limited the amount and duration of full-contact activities during high school football practice sessions. This study prospectively documents a 57% decrease in concussions sustained in practice, with no change in concussion rate in competitions, after the implementation of a rule change to limit contact in practice. While the overall decrease in concussion rate in 2014 was not statistically significant, it is a positive sign that the rule changes implemented by the WIAA were followed by a decrease in practice concussions and no change in the concussion rate in competitions. Some have argued that full contact in practice is necessary for athletes in football to learn the correct way to block, hit, tackle, receive hits, and fall. They propose that limiting contact in practice could lead to poor technique, which in turn could lead to an increased risk of injury during competition. The data in this study do not support this argument—risk of concussion during games was not increased despite a decreased amount of contact during practices. Additionally, there was no difference in concussion rate by previous football experience. The rule change limiting contact did not appear to put players with less experience at greater risk, as presumably these players with less experience were still able to learn proper technique.

The most current theory for the development of CTE is the total volume of head impacts, with the risk for CTE increasing with increased cumulative repetitive head impact exposure.[14] The goal of the WIAA rule change was to limit head impacts and thus concussion. A previous study showed that measured head impacts >14.4*g* occurred 4.3 times more often in contact practices than noncontact practices,[3] and that measured head impacts in practice decreased by 42% after contact practices were limited to 2 days per week. It is likely that the contact limitation by the WIAA had similar effects to decrease the total volume of head impacts experienced by the athletes during practice throughout the year. This is a positive step in the protection of athletes.

Other rule changes have been implemented in an attempt to limit contact and high-impact collisions. The NFL (National Football League) has moved kickoffs up 5 yards, modified where athletes on the kickoff and kick return team can stand before the kick, changed blocking rules before the returner catching the ball, begun spotting the ball 5 yards further to the 25-yard line for a touchback, and created rules on using the helmet to initiate contact. The Ivy League limited the number of contact practices allowed[10] and implemented new kickoff rules, which resulted in more touchbacks and 81% fewer concussions on kickoffs.[24] The NCAA (National Collegiate Athletic Association) implemented a rule allowing kick returners to fair catch the ball anywhere inside the 25-yard line, and the ball would then be placed at the 25-yard line. At the NFL, NCAA, and high school levels, there are "targeting" rules in place to eliminate hits to the head and neck area of defenseless players. Football and other sports should continue to identify strategies that make their sports safer.

There are several limitations to this study. Head impacts were not measured in this study; therefore, there are no measurements of the change in the volume of head impacts after the practice rule change, although Broglio et al[5] documented a decrease in measured head impacts after implementation of a rule limiting contact. Given the data collection by ATs, there may be some classification bias for what was recorded as full-contact, drill

contact, or noncontact practice. While this may slightly affect rates of concussion by practice type, it does not change the overall 57% decrease in concussions in practice after the implementation of the rule change. The study may have been underpowered to detect an overall decrease in concussion rate. A larger sample may have been able to detect a significant difference in overall concussion rate. Rates of other injuries were not documented in this study. The argument for needing full-contact practice to learn how to properly hit, block, tackle, receive hits, and fall can be used for all injuries, not just concussions. It is important to know if the practice rule changes led to any changes in injury rates for all other injuries in practices and competitions. Analyses on individual position groups were not performed, owing to position changes throughout the year, athletes playing positions on offense and defense, concussions occurring during drills in which there is no defined position, and the lack of power in the size of position groups. In addition, there was not enough power to compare mechanism of injury before and after the rule change. Future studies should try to determine how rule changes affect players by position groups and mechanism of injury. Also, there were data on days lost from competition because of concussion but not the number of days of symptoms, which would be a better measure of concussion severity. There is also no information on adherence to the new rule, coaches' satisfaction or dissatisfaction with the rule, and coaches' perception of their ability to get their teams prepared to play in competitions with the new rule. It is possible that coaches did not adhere to the contact rules, although unlikely because the rate of concussion dropped after the implementation of the rule. A coach's satisfaction, or lack thereof, with the new rule and one's perception of the ability to be prepared for competitions are important for adherence to the rule and whether the rule was too restrictive of contact or perhaps could even restrict contact more. Anecdotally, one author (A.Y.P.) was coaching eighth-grade youth football at the time of the rule change in Wisconsin, and his youth football league adopted the WIAA rule change. Initially, there was some groaning and complaining among coaches, but with a little bit of extra planning and adjustments to drills and practice schedules, the rule was fairly easy to adhere to. Finally, time series studies are inherently limited—in this case, because of the potential changes in AT staffing and coaching, the potential pressure from coaches on players and medical staff, the media attention and changing attitudes on head injuries, and the evolving changes in clinical practice regarding concussion.

In summary, the WIAA implemented a rule change before the 2014 football season to decrease contact during practice, with a resultant 57% decline in concussions in practice but without a change in concussion rates in competitions. This shows that targeted rule changes can have a beneficial effect on lowering the risk for concussion. Future research should first focus on determining when and where injuries and head impacts occur most often, through well-designed studies with athlete self-report, AT reporting, accelerometers, and video analysis whenever possible. Then, changes can be made to decrease concussion, head impact risk, and musculoskeletal injuries, and researchers can prospectively determine whether the rule changes intended to decrease concussions, head impacts, and musculoskeletal injuries in fact did so. Currently, more concussions occur in games than practices, and strategies to decrease injuries should focus more on games but still include efforts to decrease injuries in practice. These strategies should then be implemented and measured to determine if the changes do decrease injury burden. This research should include large population-based studies as well as smaller studies with helmet accelerometers to measure actual head impacts.

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