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original research

Washington State's Lystedt Law in Concussion Documentation in Seattle Public High Schools

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Context: The Lystedt law requires high school athletes who have sustained a concussion to be removed from practice and play and not to be allowed to return until cleared by a medical professional.

Objective: To determine the effect of the Lystedt law on injury and concussion documentation in the Seattle public high schools.

Design: Cross-sectional study.

Setting: Seattle public high schools.

Patients or Other Participants: The numbers of students, aged 13 to 19 years in the 2008–2009, 2009–2010, and 2010–2011 school years, were 4348, 4925, and 4806, respectively.

Main Outcome Measure(s): All injuries documented in SportsWare by athletic trainers in Seattle public high schools. We evaluated all injuries, including concussions recorded during the 2008–2009 school year, before the Lystedt law, and during the 2 school years after the law took effect (2009–2010 and 2010–2011). Incidence rates before and after the law were estimated and compared.

Results: The concussion rate was −1.09% in 2008–2009, 2.26% in 2009–2010, and 2.26% in 2010–2011. A comparison of relative risks showed that the incidence rates of concussions were different before and 1 year after the Lystedt law (relative risk = 2.10; 95% confidence interval [CI] = 1.50, 2.93) and 2 years after the law (relative risk = 2.10; 95% CI = 1.49, 2.93). Overall, the mean number of days out of play after 2008–2009 was almost 7 days greater after the law took effect (difference = 6.9 days; 95% CI = 0.70, 13.1). For females, the mean number of days out of play after 2008–2009 was more than 17 days in 2009–2010 (difference = 17.2 days; 95% CI = 4.81, 29.5) and was more than 6 days in 2010–2011 (difference = 6.3 days; 95% CI = 1.62, 11.0).

Conclusions: The number of documented concussions more than doubled after the institution of the Lystedt law, which may be attributed to heightened awareness and closer monitoring.

Key Words: concussion incidence, sports injuries, adolescents

Key Points

- After the Lystedt concussion law in Washington State was passed, the number of concussions documented in high schools in the Seattle public school district more than doubled.
- Family and mandatory coach education, the presence of athletic trainers on the field, and a restrictive return-to-sports policy might have influenced the increase in concussion documentation.

A *concussion* is a form of a mild traumatic brain injury, which is defined by the Centers for Disease Control and Prevention as a complex pathophysiologic process resulting from direct or indirect traumatic biomechanical forces to the head.[1] The forces transmitted to the head disrupt neuronal membranes, which causes a metabolic imbalance within the brain. Typically, concussion results in "short-lived impairment of neurologic function that resolves spontaneously."[2(p435)] Common symptoms include severe headaches, changes in alertness, and sometimes loss of consciousness. Concussion can also lead to permanent psychological impairments and increase the risk for subsequent concussions. Grave, and even fatal, consequences can occur if sports concussions are mismanaged in young athletes and the athlete is allowed to return to play too quickly after a concussion.[3] One such entity, second-impact syndrome, is postulated to occur when an athlete incurs a second mild traumatic brain injury while still symptomatic from an initial injury. This second impact causes massive cerebral swelling and catastrophic damage to the brain.[3,4] Although second-impact syndrome remains somewhat controversial in definition,[5] there is uniform agreement that youth athletes should not be returned to play until they are asymptomatic from any concussion or head injury.[2]

An estimated 7 million athletes participate in high school and college-level sports.[6] Approximately 1.6 to 3.8 million concussions occur during sports and recreation per year in the United States.[7] A conservative annual estimate of sports concussion among high school athletes is 400 000 events in the United States.[8] McCrea et al[9] found that only two-thirds of athletes recognized when they have had a concussion and only 43% reported it. These athletes are potentially at a higher risk for repeat concussion, which can lead to prolonged symptoms or possible catastrophic injury.

Until 2009, no legislation addressed concussion reporting, documentation, and management. The first concussion law in the nation was signed on May 14, 2009, by the

governor of the state of Washington, after a devastating head injury in a junior high school football player on October 12, 2006. Zackery Lystedt, then a 13-year-old athlete, suffered an initial concussion in the second quarter of the game and was allowed to return to play, despite having a headache, confusion, and difficulty remembering the plays. He sustained many more blows, and at the end of the game, he collapsed in his father's arms. He subsequently underwent emergency brain surgery and survived but with significant neurologic injury and permanent disability.[10]

The Lystedt law went into effect in July 2009 and has 3 essential components[11]:

1. Education of athletes and parents or guardians about concussion. The athlete and parent or guardian must sign and return a form that provides this information. The mandatory coach's education occurs through the Washington Interscholastic Activities Association (Renton, WA).
2. Removal of a youth athlete from practice or play at the time of a suspected concussion or head injury.
3. Return to practice or play only with the written permission of a licensed health care provider trained in the evaluation and management of concussion.

The law was passed with the expectation that it would lead to increased concussion awareness among young athletes, parents, and coaches; better diagnosis and management of mild traumatic brain injuries; and ultimately decreased incidence of severe brain injury.

Our objective was to determine the effect of the Lystedt law on concussion documentation in high school athletes. To achieve that aim, we compared the incidence rates for documented concussions, as well as for all injuries, before and after the law. We hypothesized that there would be an increase in the number of documented concussions when compared with other injuries. We also hypothesized that athletes would average more days out of practice and play for a concussion diagnosis after passage of the law because of a greater awareness by coaches, students, and parents about the risks of returning to play prematurely.

METHODS

After obtaining institutional review board approval, we retrospectively evaluated all documented injuries, including concussions, collected by the Seattle Public Schools' athletic trainers (ATs) using the SportsWare database (Sportsware Injury Tracking Software, Computer Sports Medicine Inc, Stoughton, MA), starting in 2008. All 10 of the high schools from the Seattle Public Schools district participated in the study. Because all data collected were anonymous, a waiver of consent from the Seattle Children's Hospital institutional review board was obtained. Injuries, including concussions, incurred by high school athletes between the ages of 13 and 19 years were recorded during the 2008–2009 school year, before the instatement of the Lystedt law, as well as during the 2 academic years after the law took effect (2009–2010 and 2010–2011).

The Seattle Public Schools district is the largest kindergarten through grade 12 school system in the State of Washington, serving more than 48 500 students in 96 schools. Students are from different socioeconomic backgrounds, 120 languages are spoken, and 40% of students are eligible for free or reduced-price lunches.

Ten high schools within the district serve 11 500 students. High school students participate in the following sports: baseball, basketball, cross-country, football, gymnastics, soccer, softball, swimming, tennis, track and field, volleyball, and wrestling. An AT is present at each high school 20 h/wk, staffing selected games and practices and maintaining athletic training room hours.

All injuries in this study, including concussions, were documented in the SportsWare database after they were reported to, and evaluated by, the ATs. A *concussion* was defined as a documented concussive injury in the SportsWare database by the school AT. The ATs for the Seattle Public Schools entered each injury into the SportsWare database and documented the total days out of play. Concussions were reported either on-site by the coach, student, or parent after an event in practice or in a game or by the student or parent after a head injury that occurred outside of school sports. Concussions were diagnosed by the AT based on the history and physical examination using physician-approved clinical criteria from the Sport Concussion Assessment Tool (SCAT; before November 2008) and from the SCAT2 (after November 2008) and entered in the database.

The data for all injuries, including concussions, were classified by the number of days lost from play: <7 days, between 7 and 21 days, and >21 days. An *athlete-exposure* (AE) was defined as 1 athlete's participation in a practice or competition. Exposures were estimated based on the number of student–athletes and the number of practices and games for each sport. The overall concussion rate was reported as the ratio of concussions per 1000 AEs. Rates were also estimated by individual sport and reported per 1000 AEs. Incidence ratios were calculated with 95% confidence intervals (CIs). We investigated the association between the concussion rates and the periods before and after the concussion law took effect using relative risk (RR) regression. The model allows us to estimate RRs and test for differences in the rates of documented concussions between periods.

We investigated whether the mean number of days out of practice or play differed before and after establishment of the Lystedt law using linear regression analysis and robust (sandwich) variance estimates. Linear regression permits a comparison between the mean number of days out of practice or play among the 3 periods in a single analysis. The robust variance estimates provided valid inference for testing for differences in the mean number of days, even in the presence of non-normality and variance heterogeneity. We also investigated sex differences for the mean number of days out due to concussions by period, stratified by sex, using linear regression analysis with robust variance estimates. Data were analyzed using Stata software (version 12.0; StataCorp LP, College Station, TX). All hypothesis test statistics were Wald statistics. All reported P values were 2 sided.

RESULTS

The numbers of students participating in sports in the 2008–2009, 2009–2010, and 2010–2011 academic years were 4348 (girls, n = 1865, 42.9%; boys, n = 2483, 57.1%),

Table 1. Number of Injuries and Concussions Documented in the 2008–2009, 2009–2010, and 2010–2011 Academic Years

	Total Injuries[a]			Concussions		
	2008–2009	2009–2010	2010–2011	2008–2009	2009–2010	2010–2011
Documented events, No.	419	579	529	48	114	111
All athletes, No.	4348	4925	4806	4348	4925	4806
Event rates, %	9.6	11.8	11.0	1.1	2.3	2.3
Females						
Events, No.	114	167	161	9	25	35
Athletes, No.	1865	2098	2057	1865	2098	2057
Event rates, %	6.1	8.0	7.8	0.5	1.2	1.7
Males						
Events, No.	305	412	368	39	89	76
Athletes, No.	2483	2827	2749	2483	2827	2749
Event rates, %	12.3	14.6	13.4	1.6	3.1	2.8

[a] Total injuries include documented concussions.

4925 (girls, n = 2098, 42.6%; boys, n = 2827, 57.4%) and 4806 (girls, n = 2057, 42.8%; boys, n = 2749, 57.2%), respectively. In the 3 years studied, 1527 total injuries were documented, 273 (17.9%) of which were concussions. Overall, the number of documented concussions and total injuries increased after the Lystedt law went into effect. The total number (and rate, per number of athletes) of documented injuries increased from 419 (9.6%) in 2008–2009 to 579 (11.8%) in 2009–2010 and slightly decreased to 529 (11.0%) in 2010–2011. The number of injuries reported by female students increased from 114 (6.1%) in 2008–2009 to 167 (8.0%) and decreased to 161 (7.8%) in 2010–2011. For male students, the number of injuries reported increased from 305 (12.3%) in 2008–2009 to 412 (14.6%) in 2009–2010 to 368 (13.4%) in 2010–2011 (Table 1).

In 2008–2009, before the Lystedt law took effect, 48 of 419 (11.5%) of all documented injuries were concussions; in 2009–2010, 114 of 579 (19.7%), and in 2010–2011, 111 of 529 (21.0%) were concussions. The number of documented concussions increased in the 2 years after the passing of the Lystedt law as compared with the year before. The number (and rate) of documented concussions increased from 48 (1.1%) in 2008–2009 to 114 (2.3%) in 2009–2010 and to 111 (2.3%) in 2010–2011 (Table 1). The number of documented concussions in female students increased from 9 (0.5%) in 2008–2009 to 25 (1.2%) in 2009–2010 to 35 (1.7%) in 2010–2011. The total number of documented concussions in male students increased from 39 (1.6%) in 2008–2009 to 89 (3.1%) in 2009–2010 to 76 (2.8%) in 2010–2011 (Table 1).

Results of the hypothesis tests comparing the rates of documented concussions from 2008–2009 to 2009–2010 and from 2008–2009 to 2010–2011 are provided in Table 2A. The overall rate of documented concussions in 2009–2010 was more than 2 times the rate of documented concussions in 2008–2009 (RR = 2.10, 95% CI = 1.50, 2.93). Similarly, the rate of documented concussions in 2010–2011 was more than twice the rate of documented concussions in 2008–2009 (RR = 2.10, 95% CI = 1.49, 2.93). The rates of documented concussions were not different between the 2 periods after 2008–2009 (RR = 1.00, 95% CI = 0.77, 1.29).

In females, the rate of documented concussions in 2009–2010 was almost 2.5 times the rate in 2008–2009 (RR = 2.47, 95% CI = 1.16, 5.28). The rate of documented concussions in 2010–2011 was more than 3.5 times the rate in 2008–2009 (RR = 3.53, 95% CI = 1.70, 7.32). The rate of documented concussions in females in 2010–2011 appeared to trend higher compared with 2009–2010 (RR = 1.93, 95% CI = 1.86, 2.38). The result, however, was not statistically significant at the 5% significance level ($P = .171$). For males, the rate of documented concussions in 2009–2010 was 2 times the rate in 2008–2009 (RR = 2.00, 95% CI = 1.38, 2.91). The rate of documented concussions in 2010–2011 was 1.76 times the rate in 2008–2009 (RR = 1.76, 95% CI = 1.20, 2.58). The rates of documented concussions

Table 2A. Relative Risk Regression of Documented Concussions by Period

Periods	Estimated Rates	Relative Risk	SE[a]	*P* Value	95% Confidence Interval
2008–2009 (reference)	0.0109	1.00	NA	NA	NA
2009–2010	0.0226	2.10	0.3581	<.001	1.50, 2.93
2010–2011	0.0226	2.10	0.3587	<.001	1.49, 2.93
Females					
2008–2009	0.0048	1.00	NA	NA	NA
2009–2010	0.0118	2.47	0.9567	.020	1.16, 5.28
2010–2011	0.0167	3.53	1.3129	.001	1.70, 7.32
Males					
2008–2009	0.0155	1.00	NA	NA	NA
2009–2010	0.0305	2.00	0.3809	<.001	1.38, 2.91
2010–2011	0.0269	1.76	0.3433	.004	1.20, 2.58

Abbreviations: NA, not applicable; SE, standard error.

[a] Estimated SEs are for log (relative risk) estimates.

Table 2B. Days Out of Practice or Play for Documented Concussions by Period

Periods	Estimated Mean, d	Difference, d	SE[a]	*P* Value	95% Confidence Interval
2008–2009 (reference)	14.7	0	NA	NA	NA
2009–2010	21.6	6.9	3.16	.020	0.70, 13.1
2010–2011	21.3	6.6	3.67	.071	−0.58, 13.9
Females					
2008–2009	9.6	0	NA	NA	NA
2009–2010	26.7	17.1	6.19	.007	4.81, 29.5
2010–2011	15.9	6.3	2.35	.009	1.62, 11.0
Males					
2008–2009	15.8	0	NA	NA	NA
2009–2010	20.1	4.3	3.52	.222	−2.63, 11.3
2010–2011	23.9	8.1	4.92	.100	−1.58, 17.8

Abbreviations: NA, not applicable; SE, standard error.

[a] The SE represents the robust standard for the difference in the estimated pairwise means.

between the 2010–2011 and 2009–2010 periods were not different (RR = 0.88, 95% CI = 0.65, 1.19).

Comparing the number of days out of play or practice, the mean number of days after 2008–2009 was almost 7 days higher in 2009–2010 (14.7 days versus 21.6 days difference = 6.9 days, 95% CI = 0.70, 13.1) and was more than 6 days higher in 2010–2011 (14.7 days versus 21.3 days). This difference was only marginal (difference = 6.6 days, 95% CI = –0.58, 13.9). For females, the mean number of days out of play after 2008–2009 was more than 17 in 2009–2010 (9.6 days versus 26.7 days, difference = 17.1 days, 95% CI = 4.81, 29.5) and was more than 6 in 2010–2011 (9.6 days versus 15.9 days, difference = 6.3 days, 95% CI = 1.62, 11.0). For males, the mean number of days out of play after 2008–2009 was not different in either 2009–2010 (15.8 versus 20.1) or 2010–2011 (15.8 versus 23.9). These results are shown in Table 2B.

The injuries, including concussions, were sustained during the course of 293 636 AEs in 2008–2009, 335 155 AEs in 2009–2010, and 309 214 AEs in 2010–2011. As a result, the concussion rate was 0.16 per 1000 AEs in 2008–2009, 0.34 in 2009–2010, and 0.36 in 2010–2011. Incidence rates by sport are shown in Table 3 and the Figure. Football had the highest incidence rate, which increased from 0.88 per 1000 AEs in 2008–2009 to 1.5 per 1000 AEs in 2010–2011.

DISCUSSION

During the past decade, the annual concussion rates in high school and in college have increased.[12–15] More regulations, increased awareness and education, and other interventions might have lead to increased identification and reporting. Educational campaigns, such as the *Heads Up* program launched by the Centers for Disease Control and Prevention in 2005, have improved high school coaches' knowledge of how to properly evaluate and manage a concussion.[16]

The aim of our study was to analyze the effect of a particular intervention, the Lystedt law, on overall injury incidence (including concussions) in 10 Seattle, Washington, public high schools. The Lystedt law requires that youth athletes who are suspected of having sustained a concussion be removed from practice or play and not be allowed to return until cleared by a licensed health care professional trained in the evaluation and management of concussion. The law also requires athletes, parents, and coaches to be educated each year about the dangers of

Table 3. Incidence Rate of Concussions by Sport and Academic Year

	2008–2009			2009–2010			2010–2011		
Sport	Concussions, No.	AEs, No.	Incidence Rate/1000 AEs	Concussions, No.	AEs, No.	Incidence Rate/1000 AEs	Concussions, No.	AEs, No.	Incidence Rate/1000 AEs
Baseball	1	18 792	0.053	2	20 184	0.099	3	14 924	0.201
Basketball, M	1	32 880	0.030	8	34 162	0.234	4	33 396	0.120
Basketball, F	6	18 080	0.332	11	17 292	0.636	7	18 656	0.375
Cross-country	0	19 304	0	0	19 178	0	1	24 696	0.040
Football	30	34 040	0.881	59	36 516	1.616	51	33 984	1.501
Soccer, M	3	19 424	0.154	9	24 882	0.362	7	18 176	0.385
Soccer, F	0	14 392	0	5	11 830	0.423	9	19 869	0.453
Softball	2	12 880	0.155	3	15 318	0.196	5	11 080	0.451
Swimming	0	13 902	0	1	21 120	0.047	1	19 656	0.051
Tennis	0	23 364	0	0	33 825	0	0	26 910	0
Track/field, M	0	23 820	0	0	29 190	0	0	24 056	0
Track/field, F	0	21 438	0	2	22 518	0.089	0	24 056	0
Volleyball	1	16 929	0.059	1	19 224	0.052	10	18 536	0.539
Wrestling	5	14 393	0.347	15	16 850	0.890	13	15 594	0.834
Overall	48	293 636	0.163	114	335 155	0.340	111	309 214	0.359

Abbreviations: AE, athlete-exposure; F, female; M, male.

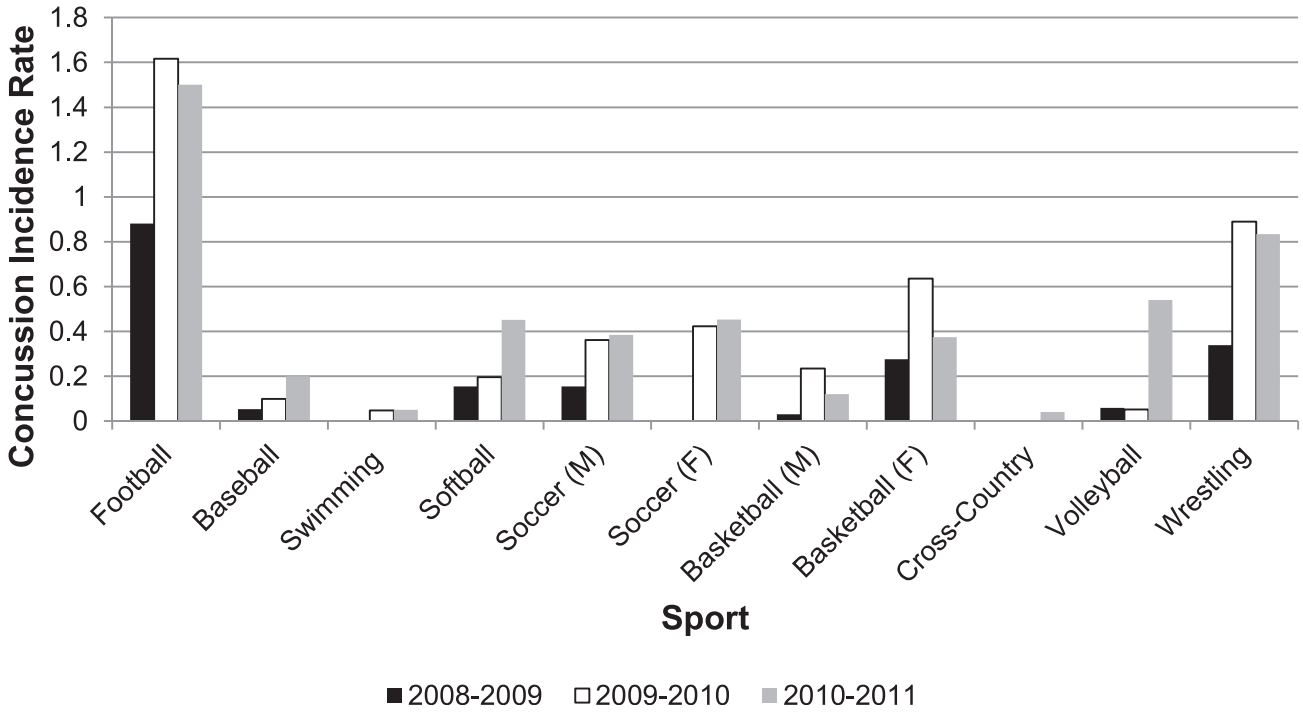

Figure. Concussion incidence rate by sport and academic year. Abbreviations: F, female; M, male.

concussion. The law has served as the foundation for similar laws passed in all 50 states.

The actual number of documented concussions and their rates increased significantly after the law. The overall rate of documented concussions in 2009–2010 was more than 2 times the rate in 2008–2009 (before the law). The rate of documented concussion for female students was more than 3.5 times the rate before the law, whereas in males, the increase was less than 2 times. Higher rates in female students compared with males have been noted before.[17–19] These authors concluded that the higher rate in females could be explained by female students reporting concussion symptoms more often than did their male counterparts. However, in the State of Washington, the Lystedt law makes reporting mandatory; therefore, the higher rate could be a function of other factors. More research should be devoted to this area.

Overall, the rise in documented concussions may reflect the increased awareness of concussions among coaches, ATs, parents, and students after passage of the law. Anecdotally, the ATs recounted numerous cases in which families approached them or the coaches to ask that their child–athlete be evaluated for concussion. These requests did not occur before institution of the law and may deserve further study. Not only might more students have reported concussions but ATs might also have become more diligent in concussion documentation and more educated in diagnosing concussions earlier.

The total number of injuries (and the rates) also increased but at a slower rate, from 419 injuries in 4348 students (9.6%) in 2008–2009 to 579 of 4925 (11.8%) in 2009–2010 and 529 of 4806 (11.0%) in 2010–2011. Some, but not all, of that increase in documented injuries can be explained by the increase in documented concussions.

Before passage of the Lystedt law, rates of documented concussions were 11.5% (48 of 419) of total injuries (2008–2009). After the Lystedt law went into effect, rates of concussion increased to 19.7% (114 of 579) and 21.0% (111 of 529) in subsequent years. Gessel et al[17] reported a concussion rate of 8.9% in high school athletes during the years 2005–2006, and Marar et al[20] observed a concussion rate of 13.2% from data collected in 2008–2010.[21] Rates of documented concussions before the law were commensurate with published rates from previous studies. Thus, the documentation rate before the law was not less than expected, and with the institution of the Lystedt law, documented concussions increased beyond the rates in previously published baseline studies. This increase could be explained by more concussions being reported and documented after the law compared with other injuries.

The number of documented concussions also increased as described by AEs. Rates increased from 0.163 per 1000 AEs in 2008–2009 (before the Lystedt law) to 0.340 in 2009–2010 and 0.359 in 2010–2011. Gessel et al,[17] Lincoln et al,[12] and Marar et al[20] reported concussion rates per 1000 AEs of 0.23, 0.24, and 0.25, respectively. Our initial values were lower than rates found in other studies, but later rates exceeded them. Overall, the incidence rate ratio of concussions for all sports was significantly different before and after the law, which shows a definitive and positive effect of the surveillance system stipulated by the law.

The incidence rate for football in our study (0.88) before the law was higher than that reported by Gessel et al[17] (0.47), Schultz et al[22] (0.33), and Powell and Barber-Foss[19] (0.59). These differences could be a function of documentation patterns. The authors mentioned above used national surveillance data in which ATs have up to 1 month to document injuries. In our schools, ATs are present at every

practice and game, and they must enter the injury information in SportsWare within 48 hours.

We hypothesized that the number of days out of play because of concussions would be higher after the law, reflecting increased caution in managing postconcussion return to play. We found a difference in days out of play before and after the law took effect (almost 7 days higher), which might be attributed to heightened awareness of concussion, closer monitoring, and an overall more careful approach to concussion management.

For females, in particular, the out-of-play mean was more than 17 days after the law. As noted above, sex differences have been seen in previous studies.[23–26] Future researchers should look at risk factors in the female population.

This study had several limitations. First, the ATs from the 10 schools where the study was conducted were all hired at the start of the 2008–2009 school year and had not yet had a chance to establish a relationship with their athletes. Second, 2008–2009 was the first year that the AT staff used the SportsWare reporting system. As ATs became more familiar with the documentation system, they might have become more diligent in documenting concussions.

SportsWare itself has its limitations. Diagnostic tools, such as SCAT2, cannot be uploaded to the system; therefore, ATs need to enter all the evaluation information for each injury. We performed a thorough data-cleaning process to create a reliable set of data. The assistance of ATs who know the system well and can detect errors was essential for this study.

Perhaps the greatest limitation of this study also highlights the most important aspect of safety for the athletes: the role of the AT. This study was conducted with ATs documenting and often managing the injuries and concussions. Our study included only schools that had ATs present on a daily basis. Without that presence, we have no accurate means of following concussion incidence. Without surveillance, we would not know whether the Lystedt law was being rigorously upheld or whether there was consistency in removing athletes with concussions from play. It is possible that, without an AT present at the school, concussions and other injuries could go undiagnosed and underreported. Also, having ATs present in the high schools allows the AT and athlete to develop a relationship, which enables the AT to educate the athletes regarding concussion and to build trust regarding concussion management. The relationship between the AT and the athlete is important for making safety a priority and the health of the athlete paramount.

Another potential limitation is the type of schools participating in this study, which were limited to those in the Seattle metropolitan area. The State of Washington is diverse, and the results of this study might not be generalizable to the more rural sections of the state. Future longitudinal studies are needed to investigate the statewide effect of the Lystedt law. Two studies based on surveys suggest that there is a gap in knowledge and practice of the Lystedt law across the state.[27,28] Additional research is required to monitor trends of documentation within Washington to see whether they remain stable across the state. Furthermore, a comparison among states that passed similar laws could show the laws' effects at the national level. Finally, future investigations are needed to scientifically measure the effect of other interventions or educational programs created to decrease the number of concussions among high school students.

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