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original research

Mandated High School Concussion Education and Collegiate Athletes' Understanding of Concussion

Miriam Carroll-Alfano, MS

Department of Communication Sciences and Disorders, St Xavier University, Chicago, IL

Context: Concussions in student-athletes are a serious problem. Most states have enacted legislation mandating concussion education for student-athletes, under the assumption that education leads to better self-reporting of concussions and improved knowledge of symptoms.

Objectives: (1) To determine the effect of state-based concussion legislation on the proportion of student-athletes receiving concussion education and to assess the moderation of this effect by gender and sport and (2) to assess the effect of concussion education on student-athletes' knowledge of concussion symptoms and likelihood of seeking treatment after a concussion.

Design: Cross-sectional study.

Setting: Private university.

Patients or Other Participants: A total of 249 National Association of Intercollegiate Athletics collegiate athletes attending St Xavier University; 160 were surveyed prelegislation and 89 were surveyed postlegislation.

Main Outcome Measure(s): Participants completed an anonymous survey that assessed previous involvement in concussion-education programs, degree of self-reporting after a concussion, and ability to enumerate symptoms.

Results: The number of athletes who reported having received education increased after the implementation of concussion legislation; however, almost 25% still reported not having received education. Athletes who played football were more likely to report having received education than those who played volleyball. The student-athletes' ability to name a diversity of concussion symptoms or to report seeking medical attention after a concussion did not improve in the postlegislation period relative to the prelegislation period.

Conclusions: Legislation has been passed in all 50 states to address concussions in student-athletes; however, improvements are still needed. Concussion education must be delivered in a uniform, effective manner to all student-athletes across sports and genders. Concussion education should emphasize the diversity of symptoms, especially cognitive and behavioral symptoms. We must develop and disseminate evidence-based educational programs that are clinically proven to be effective in improving athletes' knowledge and behaviors.

Key Words: legislation, student-athletes, traumatic brain injuries

Key Points

- More student-athletes reported receiving concussion education after legislation was passed; however, nearly 25% of athletes reported not receiving such education.
- Athletes with as well as those without concussion education exhibited poor awareness of the cognitive and behavioral symptoms of concussion.
- Evidence-based concussion education should be delivered to all student-athletes.

The Centers for Disease Control and Prevention has estimated that up to 3.8 million concussions occur annually in the United States from participation in sporting and recreational activities.[1] Many of these concussions affect adolescents, especially those who participate in organized sporting activities. Adolescents may be more vulnerable to the serious effects of concussions and may have longer recovery times than adults.[2,3] Concussion-induced cognitive deficits are particularly serious for adolescents because they can adversely affect academic performance.

Although awareness of the serious long-term health sequelae of concussions has increased, serious concerns remain that (1) student-athletes underreport concussion symptoms[4–7] and (2) this might reflect inadequate knowledge of such symptoms.[7] Student-athletes consistently fail to self-report when experiencing concussion symptoms.[4,8–11] Additionally, deficits in student-athletes' knowledge of concussion symptoms, especially cognitive and behavioral symptoms, have been demonstrated.[11–14]

In 2009, Washington was the first state to pass a concussion law designed to protect student-athletes.[15] Subsequently, all 50 states and the District of Columbia have enacted concussion legislation, with 43 of the 51 requiring mandatory concussion-education programs for student-athletes.[16] The underlying assumption of concussion legislation is that mandating concussion education for high school athletes will lead to *improved outcomes*, typically defined as better self-reporting of and increased health care utilization rates for concussion injuries, as well as enhanced knowledge of concussion symptoms.

In spite of ubiquitous legislation, few investigators[11,17] have probed whether a law requiring concussion education for student-athletes results in all athletes receiving this education. Also, researchers examining the effect of concussion education on self-reporting and health care

utilization rates have found mixed results, with some finding increased self-reporting or utilization[18] and others reporting no improvement.[6,8,14] Still other studies showed that mandatory education had no effect on athletes' awareness of the diversity of concussion symptoms,[12,19] and, even when education resulted in increased knowledge of symptoms, such increased knowledge did not lead to more self-reporting.[8,20–22]

These results call into question the underlying assumptions of those portions of concussion legislation that mandate student-athlete education: that legislation will lead to all student-athletes receiving concussion education and that this improved access to education will lead to better outcomes regarding concussion knowledge and self-reporting. Although such legislation may benefit student-athletes, it may not be enough to address this complex problem.

I aimed to address 4 research questions. First, is the passage of state concussion legislation associated with an increase in high school athletes who report having received concussion education when they get to college? Second, are there differences in the rates of athletes receiving concussion education based on sport played or gender? Third, are athletes who report having received training and having had a concussion more likely to say that they sought treatment for the concussion relative to those who report not having received training? Finally, are athletes who report having received concussion education better able to name the diverse symptoms of concussion?

METHODS

Research Design

This research used a cross-sectional design. The summer 2011 enactment of legislation mandating concussion education in Illinois[23] and Indiana[24] provided an opportunity to perform this study. The Illinois legislation required that the Illinois High School Association make available to school districts educational materials about concussions, such as videos and written materials. It also compelled school districts to use these educational materials to educate coaches, student-athletes, and parents about the nature and risks of concussions.[23] The law did not specify how this education should be delivered or the precise nature of its content. The law also directed that each school board adopt a policy regarding concussion to comply with the policies of the Illinois High School Association. The Indiana legislation required state education officials to distribute guidelines and educational information about concussions to all schools.[24] Schools were then required to have athletes and their parents or guardians receive this educational information and sign a form acknowledging receipt. No penalties for noncompliance were explicitly described in either piece of legislation.[23,24]

I invited student-athletes to take an anonymous survey of knowledge about concussions immediately before participating in an hour-long concussion-education session. All procedures were approved by the university's Human Subjects Institutional Review Board. Data were gathered during 11 training sessions conducted between March 2012 and April 2014.

This study was a natural experiment: the legislation provided the opportunity to compare students' concussion education and knowledge prelegislation and postlegislation as they continued their athletic participation in college. During the initial session (spring 2012), all participants had graduated from high school before the period when mandated high school concussion education in Illinois and Indiana would have been offered to them as a result of legislation. In subsequent years, entering freshman students who participated in the study had graduated after the time when education activities mandated by legislation should have been offered. Thus, it was possible to achieve a comparison between cross-sectional groups who had graduated from high school before and after the time when legislatively mandated concussion education should have been offered. If the new mandates were 100% effective, all students in the postlegislation period should have reported participating in mandatory concussion education in high school, as opposed to those in the prelegislation period, when education was voluntary. The percentage of students receiving training would thus be expected to increase from some initial nonzero level (because some high schools were already providing training voluntarily) to 100% postlegislation. We relied on the students' accurate reporting of their participation in high school concussion training and response to having a concussion, if one had occurred.

Data-Collection Instrument

The data-collection instrument was a brief written survey that included open-ended and multiple-choice questions. The following information was collected:

- Demographic information (sport, gender, year in college).
- Whether the participant had previously attended a concussion training program.
- Whether the participant had ever experienced a concussion and, if so, whether treatment was sought.
- What concussion symptoms the participant was able to enumerate in an open-ended question.

The survey is provided in the Appendix. By necessity, the survey was kept very brief, as only a few minutes were available for administering the survey before the concussion-education program.

Participants

We examined 249 National Association of Intercollegiate Athletics athletes attending St Xavier University. Of the student-athletes who were invited to participate in this study, more than 90% agreed to do so. The survey was anonymous, with no personally identifying information collected. Recruits consisted of men (67%) and women (33%) participating in various sports: basketball (12 men, 13 women), cross-country/track (15 men, 8 women), football (104 men), soccer (21 men, 24 women), softball (20 women), volleyball (14 men, 13 women), and other sports (1 man, 4 women). Approximately 64% (n = 160) of participants had graduated from high school before the Illinois and Indiana concussion legislation took effect. The remaining 36% (n = 89) had been in high school after the

legislation went into effect. Approximately 90% of the student-athletes at this university had attended 75 high schools in Illinois; the majority of the remainder attended high school in Indiana.

Data Analysis

Analyses were performed using SPSS (version 22; IBM Corp, Armonk, NY). We used a 2-tailed Pearson χ^2 test to assess the statistical significance of the association of legislation with having received concussion training, as well as the association of gender with having received concussion training. For the association of having received concussion education and gender with having sought treatment after a concussion, some individual cell sizes were less than 5; therefore, a Fisher exact test was used. An α level of $P < .05$ was considered statistically significant. For statistically significant results, the odds ratio was calculated. For analysis of the association of training with sport played and gender, logistic regression was performed.

Symptoms of concussions vary in both the exact symptom lists and categorization of symptoms into discrete groups.[25–27] We used a modified version of the Stoler and Hill[26] classification, wherein their 4 categories (cognitive, physical, behavioral, and emotional) were reduced to 3, combining the emotional and behavioral categories into a single behavioral category. These categories were combined because of the close relationship between symptoms in the 2 categories (eg, *frustration and anger* in the emotional category relates to *explosive temper* in the behavioral category). Thus, symptoms were classified as physical, cognitive, or behavioral. Judgment was required for some classifications, as respondents commonly gave colloquial terms for medical conditions (eg, *ringing in the ear* for tinnitus or *sick to your stomach* or *throwing up* for nausea and vomiting). Responses not matched to recognized symptoms were marked invalid and not counted in subsequent analyses.

RESULTS

Association of Concussion Legislation With the Proportion of High School Athletes Who Reported Receiving Education

To determine if legislation was associated with a greater likelihood of athletes reporting prior concussion education, responses were compared for 2 groups: students who had graduated from high school before high school concussion education was mandated as a result of legislation and students who had graduated after the point when mandated education should have been offered. Of the students who had graduated from high school after education was mandated, 76.4% (68 yes, 21 no) reported having received training, a value that was higher than for those who had graduated before this time, of whom 59.4% (95 yes, 65 no) reported having received training ($\chi^2_1 = 7.335$, $P = .007$, odds ratio = 2.22, 2-tailed Pearson χ^2).

Association of Sport Played and Gender With Reporting Having Received Concussion Education

The cross-sectional groups were further split by gender to probe for differences in training rates between men and women. No difference was found in the prelegislation period ($\chi^2_1 = 1.285$, $P = .257$, 2-tailed Pearson χ^2), with 62.4% of men (68 yes, 41 no) and 52.9% of women (27 yes, 24 no) reporting having received training. Similarly, in the postlegislation period, no difference was observed ($\chi^2_1 = 3.729$, $P = .053$, 2-tailed Pearson χ^2), with 82.8% of men (48 yes, 10 no) and 64.5% of women (20 yes, 11 no) reporting having received training.

After the data were stratified by the prelegislation and postlegislation periods and by gender, some of the resulting cell sizes were small ($\sim$10). Thus, this χ^2 analysis had low statistical power, which can lead to type II error. It is premature to conclude that no differences existed between genders, as studies having larger sample sizes and greater statistical power may yield different results.

The proportion of athletes by sport who reported having received training is shown in Figure 1. Football players had the highest percentage and volleyball players, the lowest. We analyzed the data using logistic regression with gender as a possible confounder, as sport and gender are dependent in some cases (eg, all football players are male). Three models were considered in the regression. The first used sport as the independent variable, the second used sport and gender as variables, and the third used sport, gender, and the interaction between sport and gender (sport $\times$ gender) as variables.

For prelegislation athletes, model 1 showed significant improvement relative to the constant model ($\chi^2_5 = 22.28$, $P < .001$) with a moderate effect size ($R^2 = 0.103$ [Hosmer and Lemeshow], $R^2 = 0.130$ [Cox and Snell], and $R^2 = 0.175$ [Nagelkerke]). Model 2 ($\chi^2_6 = 22.32$, improvement in $\chi^2 = 0.04$, $P = .847$) and model 3 ($\chi^2_9 = 28.67$, improvement in $\chi^2 = 6.36$, $P = .096$) did not result in significant improvement relative to model 1 and were thus discarded.

The results of the logistic regression for prelegislation athletes using model 1 are provided in Table 1, using football as the baseline. Playing volleyball was a significant factor in whether an athlete reported having received training ($P < .001$; odds ratio 95% confidence interval = 0.010, 0.241), with prelegislation athletes who played volleyball being significantly less likely to have received training than those who played football.

For postlegislation athletes, model 1 exhibited a significant improvement in the fit relative to the constant model ($\chi^2_5 = 16.60$, $P = .005$), with a moderate effect size ($R^2 = 0.180$ [Hosmer and Lemeshow], $R^2 = 0.179$ [Cox and Snell], and $R^2 = 0.260$ [Nagelkerke]). Model 2 ($\chi^2_6 = 16.66$, improvement in $\chi^2 = 0.05$, $P = .818$) and model 3 ($\chi^2_9 = 20.18$, improvement in $\chi^2 = 3.52$, $P = .317$) did not result in significant improvement relative to model 1 and were discarded.

Results of the postlegislation logistic regression for model 1 are shown in Table 2. Playing volleyball ($P = .001$; odds ratio 95% confidence interval = 0.010, 0.332) or basketball ($P = .005$; odds ratio 95% confidence interval = 0.010, 0.432) were significant in whether or not an athlete had received training, with athletes in these sports being less likely to have received training relative to those in football.

After the data were stratified by the prelegislation and postlegislation periods and by sport, some of the resultant cell sizes were small ($\sim$5–10). Thus, these logistic

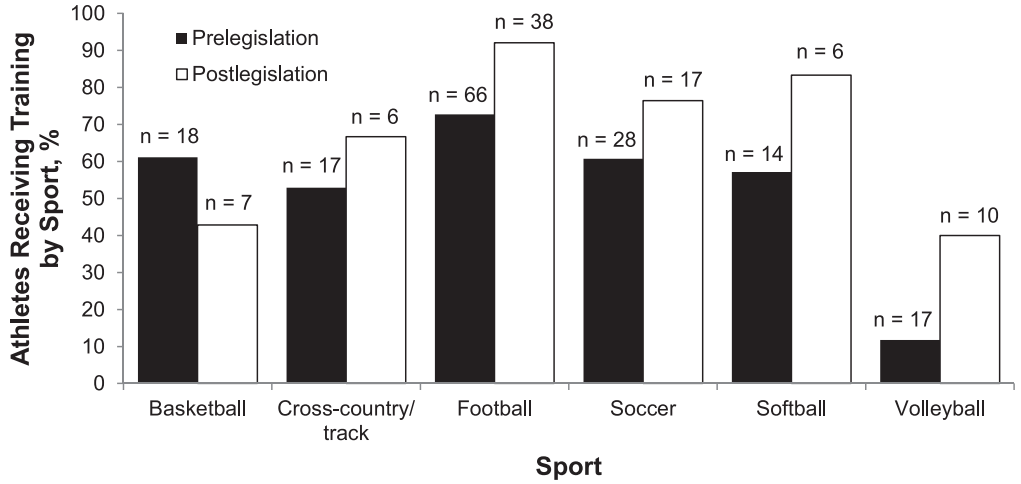

Figure 1. Percentage of athletes who received concussion training by sport.

regressions had low statistical power, which can lead to type II error. It is premature to conclude that the differences noted above are the only significant differences that exist among sports, as studies having larger sample sizes and greater statistical power may yield different results.

Likelihood of Athletes Seeking Treatment After Experiencing a Concussion

Of 249 respondents, 79 (31.7%) reported having previously experienced a concussion. Of these 79 athletes, 49 (62.0%) stated that they had sought treatment after experiencing a concussion and 30 (38.0%) stated that they did not seek treatment. Of the 79 athletes who reported having sustained a concussion, 59 (74.7%) were men and 20 (25.3%) were women. Of the 59 men who had experienced a concussion, 33 (55.9%) had sought treatment, whereas of the 20 women who had experienced a concussion, 16 (80%) had sought treatment.

Prelegislation, 69.0% (20 yes, 9 no) of athletes who had received training sought treatment after experiencing concussion symptoms and 43.8% (7 yes, 9 no) of athletes who had not received training sought treatment. This difference was not statistically significant ($P = .122$, 2-tailed Fisher exact test). Postlegislation, 61.3% of athletes (19 yes, 12 no) who had received training sought treatment after experiencing concussion symptoms and 100% of athletes (3 yes, 0 no) who had not received training sought treatment. This difference was not statistically significant ($P = .537$, 2-tailed Fisher exact test).

The percentage of athletes seeking treatment after experiencing a concussion prelegislation and postlegislation was examined by gender. Of the 79 athletes who reported having experienced a concussion, 59 were men (74.7%) and 20 were women (25.3%). Prelegislation, 51.4% of men (18 yes, 17 no) and 90% of women (9 yes, 1 no) sought treatment after experiencing concussion symptoms. This difference was statistically significant ($P = .034$, 2-tailed Fisher exact test, odds ratio = 8.5). Postlegislation, 62.5% of male athletes (15 yes, 9 no) and 70% of female athletes (7 yes, 3 no) sought treatment after experiencing concussion symptoms. This difference was not statistically significant ($P = 1.00$, 2-tailed Fisher exact test).

After the data were stratified by prelegislation and postlegislation periods, by athletes having experienced a concussion, and by gender, some of the resultant cell sizes were small (<10). Thus, these Fisher exact tests have low statistical power and should be viewed as exploratory.

Table 1. Logistic Regression of Sport Versus Training Prelegislation (Model 1)[a]

Sport[b]	β Value	Odds Ratio 95% Confidence Interval	*P* Value
Constant	0.981	—	<.001
Basketball	−0.529	0.198, 1.755	.342
Cross-country/track	−0.863	0.141, 1.262	.123
Soccer	−0.546	0.228, 1.472	.251
Softball	−0.693	0.152, 1.652	.253
Volleyball	−2.996	0.010, 0.241	<.001

[a] $R^2 = 0.103$ (Hosmer and Lemeshow), $R^2 = 0.130$ (Cox and Snell), $R^2 = 0.175$ (Nagelkerke). Model $\chi^2_5 = 22.28$, $P < .001$.
[b] Sports are reported relative to football, which was used as the baseline.

Table 2. Logistic Regression of Sport Versus Training Postlegislation (Model 1)[a]

Sport[b]	β Value	Odds Ratio 95% Confidence Interval	*P* Value
Constant	2.457	—	<.001
Basketball	−2.744	0.010, 0.432	.005
Cross-country/track	−1.774	0.022, 1.354	.094
Soccer	−1.278	0.055, 1.417	.124
Softball	−0.847	0.037, 4.964	.498
Volleyball	−2.862	0.010, 0.322	.001

[a] $R^2 = 0.180$ (Hosmer and Lemeshow), $R^2 = 0.179$ (Cox and Snell), $R^2 = 0.26$ (Nagelkerke). Model $\chi^2_5 = 16.60$, $P = .005$.
[b] Sports are reported relative to football, which was used as the baseline.

Table 3. Valid and Invalid Concussion Symptoms Named by Athletes

Symptom	Category	Times Named	% of Total Responses
Headache	Physical	109	24.8
Dizziness	Physical	107	24.4
Nausea/vomiting	Physical	70	15.9
Memory impairment	Cognitive	50	11.4
Blurred/double vision	Physical	19	4.3
Disorientation	Cognitive	18	4.1
Light-headedness	Physical	12	2.7
Fatigue/lethargic	Physical	11	2.5
Hypersensitivity to light	Physical	10	2.3
Impaired coordination	Physical	9	2.1
Loss of consciousness	Physical	6	1.4
Emotional lability	Behavioral	3	0.7
Decreased attention	Cognitive	3	0.7
Perceptual disturbances	Cognitive	3	0.7
Sleep disturbances	Physical	3	0.7
Decreased concentration	Cognitive	2	0.5
Depression	Behavioral	1	0.2
Chronic pain	Physical	1	0.2
Neck pain	Physical	1	0.2
Total valid symptoms		439	100
Dilated pupils	Invalid	7	—
Death	Invalid	3	—
Diarrhea	Invalid	1	—
Seizure	Invalid	1	—
Swelling of the brain	Invalid	1	—

Studies having larger sample sizes and greater statistical power may yield different results.

Knowledge of the Symptoms of Concussion

We tested athletes on their knowledge of concussion symptoms by asking them to name symptoms of a concussion. Of the 249 participants, 220 (88%) correctly named at least 1 valid symptom. Twenty distinct valid concussion symptoms were named by the respondents (Table 3). Respondents named a total of 452 symptoms, an average of 1.82 symptoms per respondent. A total of 439 of the 452 symptoms named (97.1%) were indicative of concussion.

Twenty-nine respondents (11.6%) either named an incorrect symptom or failed to name any symptoms. Thirteen of the symptoms named were not concussion symptoms and were excluded from further analysis (Table 3). Most of these were symptoms of more serious traumatic brain injuries, including dilated pupils, seizure, or death.

Generally, respondents named a limited range of symptoms. The top 4 symptoms (headache, dizziness, nausea/vomiting, and memory impairment) accounted for $>75\%$ of the total symptoms named, and the top 10 symptoms accounted for nearly 95% of the total.

Classification of the 20 distinct named symptoms into the 3 categories we used (physical, cognitive, and behavioral) is reported in Table 3. Figure 2 shows the percentage of athletes naming at least 1 symptom for each of the 3 categories, separated by athletes who had received concussion training and those who had not. Both athletes with and athletes without training were able to name at least 1 physical symptom of a concussion at a high rate (83.4% with training, 83.7% without training). For cognitive symptoms, 31.9% of athletes with education correctly named at least 1 cognitive symptom compared with 22.1% of athletes without education. This difference was not statistically significant ($\chi^2_1 = 2.854$, $P = .091$, 2-tailed Pearson χ^2). For behavioral symptoms, very few (4 of 249) named at least 1 correct behavioral symptom (0.6% with training, 3.5% without training).

DISCUSSION

Prevalence of Concussion Education Among High School Athletes

The legislation enacted in Illinois[23] and Indiana[24] in 2011 enabled us to assess the effectiveness of state legislation in promoting improved access to concussion education, better self-reporting of concussion symptoms, and improved concussion symptom knowledge. Although we examined the results of the Illinois and Indiana legislation, the portions of these laws mandating concussion education to high school athletes are also found in legislation enacted by 43 of the 50 states.

Specifically, the concussion legislation enacted by the state of Illinois required, among other things, that the Illinois High School Association make available to school districts educational materials about concussion, such as videos and written materials. It also mandated that the school districts use these materials to educate coaches, student-athletes, and parents about the nature and risks of concussions, including the risk of continuing play after a concussion.[23] The law did not specify how this education should be delivered or the precise nature of its content. No penalties for noncompliance were explicitly described in the legislation.[23]

Similarly, concussion legislation enacted by the state of Indiana required state education officials to distribute to all schools guidelines and educational information about concussions. Schools were then required to provide this educational information to athletes and their parents and have them sign a form acknowledging that they had received the information. No penalties for noncompliance were explicitly described in the legislation.[24]

The portions of the Illinois and Indiana legislation mandating concussion education were similar. In addition to these 2 states, 41 other states have enacted concussion legislation that specifically requires education for student-athletes.

This legislation should have resulted in all athletes who graduated from a high school in Illinois or Indiana and entered college in or after the fall of 2012 reporting having received concussion education before entering college. Although we found an increase in the proportion of athletes who reported having received such training during the postlegislation era, a minority (23.6%) entered college without this training. It may be unrealistic to expect full compliance with the legislation, but if the dictates of the legislation are being uniformly followed, the percentage of athletes entering college without participating in a concussion-education program should be zero.

This study examined athletes who entered college within the first 2 years of the postlegislation era. It is possible that the percentage of athletes reporting not

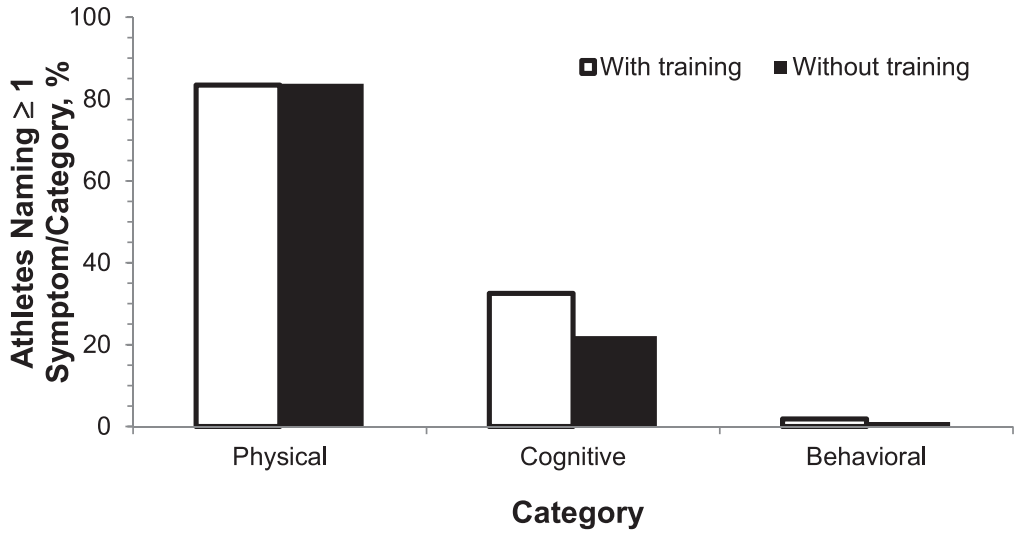

Figure 2. Percentage of athletes who named 1 or more concussion symptoms for each category.

having received concussion education will decrease in the future as more high schools comply with the dictates of the legislation.

It should be noted that before the legislation, 60% of athletes were already reporting having received concussion education. Whatever voluntary or recommended policies that school districts or high school associations may have had in place before the legislation appear to have been at least partially successful in providing concussion education for student-athletes.

The participants' self-reporting of having received education may not be completely reliable. Some athletes may have received concussion education but forgotten it, or the training they did receive may have been so minimal that they did not recognize it as being concussion education.

When we analyzed participation rates by sport, football players reported the highest rate of concussion training, at 70% prelegislation and more than 90% postlegislation. This is not surprising because concussions among football players have been widely publicized in the mass media and these athletes would therefore be expected to be the most likely to receive concussion education. Other sports exhibited participation rates ranging from the mid 50s to the mid 80s. The notable exceptions were volleyball, with a significantly lower rate than football for both prelegislation and postlegislation, and basketball, with a significantly lower rate postlegislation.

Effectiveness of Concussion Education and Training

The underlying assumption behind legislation mandating concussion education for high school athletes is that this education will lead to improved outcomes for athletes who sustain concussions by (1) instilling in athletes the need to seek medical attention when a concussion occurs and (2) helping athletes recognize the symptoms of concussion. These assumptions have received mixed support in the literature. Some authors[18] found that legislatively mandated education increased the likelihood that student-athletes with concussions would receive treatment; however, others[6,8,14] found that education was not associated with an increase in self-reporting or seeking treatment. Still other researchers[12,19] showed that mandatory education had no effect on athletes' awareness of the diversity of concussion symptoms. Even when education resulted in an increase in knowledge of concussion symptoms, that increased knowledge did not lead to increased self-reporting and treatment.[8,20–22] Factors such as athletes' beliefs and the attitudes of coaches, teammates, and parents are important.[4,6–8,10,11,17,28]

Our results also do not fully support these 2 assumptions. Athletes who received concussion education and had experienced a concussion did not report having sought medical treatment at a statistically higher rate than those without training, in agreement with other studies.[8,20–22] Of the 79 athletes who reported having experienced a concussion, with or without education, more than a third reported not having sought treatment after a concussion. In this study, athletes who had received training were not more able to name the diverse range of symptoms that indicate a concussion. A majority of athletes (~85%) with and without concussion training named at least 1 physical concussion symptom. Athletes who had received concussion education did not name a cognitive symptom at a higher rate than those without training (31.9% versus 22.1%, $P = .091$), and in both cases, the rate was low. For behavioral symptoms, only 4 athletes out of the 249 participants named a behavioral symptom. Thus, the effectiveness of concussion education, as currently being delivered, in achieving improved self-reporting of concussions and improved recognition of the diversity of concussion symptoms must also be questioned, a conclusion noted by other authors.[6,8,12,14,18,19]

Recommendations for Improved Concussion Education

Concussion legislation provides a mechanism for ensuring mandatory delivery of concussion education to student-athletes. We found that nearly 25% of athletes reported not having received concussion education, even after the

legislation took effect. Continued efforts are needed to ensure that athletes are actually receiving the mandated education and that the education is effective in changing knowledge and behavior. The results presented here suggest several ways in which the design and delivery of concussion education to student-athletes can be improved, building on recommendations from other investigators.[10,29,30]

The first recommendation is for state and local officials and educators to work with high schools and their athletic departments to determine why athletes are not reporting receiving education and to work to ensure uniform, effective delivery of concussion education to their athletes, across sports and genders. Nearly 25% of athletes in this study who matriculated to college in the postlegislation era reported not having received concussion education. Student-athletes who played certain sports, such as volleyball and basketball, reported having received concussion education less than those who played football. Either concussion education is not being delivered to high school athletes, or it is being delivered in such an ineffective manner that athletes do not recall participating a year or more later. Thus, it is not enough to pass legislation; government, educators, and athletic departments need to work together to ensure that all student-athletes receive education that meets their needs.

The second recommendation is that concussion education should emphasize the diverse nature of symptoms. Concussion education was not associated with an increased ability to recognize the full spectrum of symptoms, particularly cognitive and behavioral symptoms. Education should emphasize cognitive and behavioral symptoms, of which athletes are less aware. Recognition of cognitive symptoms is important for student-athletes, as cognitive problems, such as impaired memory, executive functioning, and attention deficits, can affect their academic studies. Recognition of behavioral symptoms is also important for student-athletes heading to college, as they are often away from home for the first time, and the loss of familial support structures can make it difficult to negotiate behavioral symptoms, such as poor judgment, depression, or impulsive behavior.

A final recommendation is for education to instill in athletes, coaches, and parents the need for a student-athlete to seek treatment after experiencing concussion symptoms. A number of studies[4,8,10] have shown that athletes with increased concussion knowledge were not more likely to seek treatment after experiencing a concussion than were athletes with less knowledge. Athletes failed to seek medical attention after experiencing concussion symptoms for various reasons, including not recognizing that they had sustained a concussion, pressure from coaches and parents to continue participation after experiencing a concussion, a culture that suggests withdrawal from play after a concussion indicates a lack of toughness and commitment, and a lack of awareness about the long-term serious consequences of concussions.

We must develop and disseminate evidence-based educational programs that have been clinically proven to be effective in increasing athletes' self-reporting of concussion. Such programs may need to extend beyond a simple provision of information to the athlete and instead be directed at improving reporting intentions by addressing attitudes, beliefs, and culture.[4,6–8,10,11,17,28] Additionally, it may be equally important for evidence-based education to be directed at coaches and parents, who serve as authority figures for student-athletes and whose attitudes and beliefs likely play a strong role in an athlete's decision to report or not report a concussion.[4,10,11,31]

Limitations

This study was a natural experiment. We made no attempt to include a control group to compare reporting behaviors for concussions versus another injury or concussion knowledge of athletes in this study with that of nonathletes who had no exposure to concussion education. Thus, it is possible that in addition to the enactment of mandatory concussion education, other factors could have affected the observed results, and the results presented here may not establish causality between concussion education and the observed outcomes. For example, the overall levels of athletic training staff and resources available to the athletes could have increased during this time, leading to a greater propensity of athletes seeking treatment for all types of injuries.

Also, during the time of this study (2012–2014), sport concussions were a topic of intense public interest and media attention. This increased public focus may have exerted a confounding effect on our results, as it may have affected athletes' concussion knowledge, independent of the effect of the legislatively mandated education.

We did not differentiate among various types of education, such as videos, in-person training, fact sheets, or required quizzes and examinations. Previous investigators[11,29,30] have found that training efficacy was influenced by training modalities and content. Furthermore, we examined the effect of legislation from only 2 states. The generalizability of the results to other states and the external validity of this research should be investigated at other universities, including those with larger athletic programs and in other regions of the country. We made no attempt to ascertain why student-athletes were still reporting that they had not received concussion education, and future authors should address this topic because legislation requiring student-athlete education is in effect in nearly all 50 states.

When we stratified the results by various criteria, such as sport played, gender, and whether the respondent had previously experienced a concussion, the resulting subsets had small populations ($\sim$10). This led to low power in the statistical analysis and a concomitant high possibility of type II error. This study should be expanded to larger sample sizes to allow for better investigation of sample subsets.

Participants were asked if they had sustained a concussion and, if so, whether they had sought treatment. Owing to time restrictions in the administration of the survey, as well as to concern about the participants' ability to identify accurately from memory the relative timeline of sustaining a concussion, seeking treatment after a concussion, and receiving concussion education, no effort was made to establish this timeline. Thus, it is possible that in some

cases, the exposure to concussion education occurred after the measured outcome of whether treatment was sought. Future work to establish this timeline would lead to stronger conclusions about the relationship between receiving concussion education and seeking treatment after a concussion.

To determine participants' knowledge of concussion symptoms, the survey simply asked participants to name symptoms of a concussion. It did not ask them to exhaustively name all concussion symptoms that they knew, nor did it explain the major categories of concussion symptoms (physical, cognitive, or behavioral) and ask them to name a symptom from each category. Therefore, it is possible that additional participants would have been able to enumerate behavioral or cognitive symptoms had the data-collection instrument been constructed differently. Further investigation of athletes' symptom knowledge in greater detail, in particular to assess athletes' knowledge of cognitive and behavioral symptoms, would be beneficial.

Appendix. Data-Collection Instrument[a]

Survey for Athletes

1. Academic year:
   Freshman
   Sophomore
   Junior
   Senior
2. Sex: Male Female
3. Sport: _____
4. Have you attended/received information regarding concussions? Yes No
5. Can you name any symptoms of a concussion?
   _____
6. Have you ever had a concussion? Yes No
7. Did you seek medical attention? Yes No

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[a] The instrument is presented in its original form.

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Address correspondence to Miriam Carroll-Alfano, MS, Department of Communication Sciences and Disorders, St Xavier University, 3700 West 103rd Street, Chicago, IL 60655. Address e-mail to alfano@sxu.edu.