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Jill Daugherty

National Center for Injury Prevention & Control, Centers for Disease Control & Prevention

Dana Waltzman

National Center for Injury Prevention & Control, Centers for Disease Control & Prevention

Katherine P. Snedaker

PINK Concussions

Jason Bouton

Sacred Heart University

Xinjian Zhang

National Center for Injury Prevention & Control, Centers for Disease Control & Prevention

See next page for additional authors

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Authors

Jill Daugherty, Dana Waltzman, Katherine P. Snedaker, Jason Bouton, Xinjian Zhang, and David Wang

RESEARCH ARTICLE

Concussion Experiences in New England Private Preparatory High School Students Who Played Sports or Recreational Activities

JILL DAUGHERTY, MPH, PhD^a  DANA WALTZMAN, PhD^b KATHERINE P. SNEDAKER, LCSW^c JASON BOUTON, MS ATC CSCS PES CMS^d
XINJIAN ZHANG, PhD^e DAVID WANG, MD MS^f

ABSTRACT

BACKGROUND Sports- and recreation-related (SRR) activities are a major cause of adolescent concussions. Most adolescent SRR concussion research has been conducted among public school students. As private schools are qualitatively different from public schools (eg, location, socioeconomic status, sports played), this study explores the concussion experiences of a large group of private high school students.

METHODS We surveyed 2047 New England private preparatory high school students who played sports or engaged in a recreational activity in 2018 about the sports they played, and their self-reported concussion experiences (eg, age at first concussion, if concussions were sports- or recreation-related). Descriptive, bivariate, and multivariate statistics are presented.

RESULTS One-third (33.0%) of students who reported engaging in sport- or recreation-related activities self-reported experiencing a concussion in their lifetime. A higher percentage of boys, students who played contact sports, and those who played multiple seasons of school sports reported a concussion. Sex, contact level of primary sport played, and age of first concussion were also significantly associated with reporting a sports- or recreation-related concussion.

CONCLUSIONS A sizeable proportion of private preparatory high school students reported experiencing a concussion, with some students at higher risk. Private preparatory high school-specific concussion prevention strategies may be needed.

Keywords: concussions; school sports; injury prevention; private schools.

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Participation in high school sports has consistently grown in the last 3 decades.¹ Whereas the benefits of sports participation are many (eg, improvements in health and emotional well-being, academic performance, and leadership and teamwork skills),²⁻⁴ risk for injury, such as concussion [also known as mild traumatic brain injury or mild traumatic brain injury (TBI)], is also inherent in sports. A concussion is caused by a bump, blow, or jolt to the head or by a hit to the body that causes the head and brain to

move rapidly back and forth. This rapid movement can cause the brain to bounce around or twist in the skull, creating chemical changes in the brain.⁵ A recent study reported that one in every 5 adolescents has experienced a concussion at some point in their lives.⁶ Additionally, research has found that concussions might be increasing over time: between 2007 and 2013, emergency department visits for TBIs among children and adolescents in the United States increased.⁷ A major cause of TBIs among youth are

^aEpidemiologist, (jdaugherty@cdc.gov), National Center for Injury Prevention & Control, Centers for Disease Control & Prevention, 4770 Buford Highway, Atlanta, GA 30341

^bBehavioral Scientist, (dwaltzman@cdc.gov), National Center for Injury Prevention & Control, Centers for Disease Control & Prevention, 4770 Buford Highway, Atlanta, GA 30341

^cFounder and Executive Director, (katherine@pinkconcussions.com), PINK Concussions, 15 Shorefront Park, Norwalk, CT 06854

^dHead Athletic Trainer, (jbouton@kingschoolct.org), NEPSAC District 4 SMAC Representative, Founding Chair, FAA Athletic Trainers Organization, Adjunct Faculty, Sacred Heart University, 1450 Newfield Avenue, Stamford, CT 06905

^eStatistician, (xaz8@cdc.gov), National Center for Injury Prevention & Control, Centers for Disease Control & Prevention, 4770 Buford Highway, Atlanta, GA 30341

^fClinical Director, (dwang01@connecticutchildrens.org), Elite Sports Medicine, Connecticut Children's Medical Center, 399 Farmington Ave, Farmington, CT 06032

Address correspondence to: Jill Daugherty, Epidemiologist, (jdaugherty@cdc.gov), National Center for Injury Prevention & Control, Centers for Disease Control & Prevention, 4770 Buford Highway, Atlanta, GA 30341.

sports- and recreation-related activities,⁸ particularly among adolescents. A 2018 national study reported that over 15% of high school students reported having at least one sport- or recreation-related concussion in the past 12 months.⁹ Studies have further suggested that children and adolescents may be at particular risk of experiencing a concussion because of specific neurological and physiological factors.¹⁰⁻¹² In addition, concussion affects children and adolescents differently compared to adults. For example, children may take longer to recover from a concussion compared to adults¹³⁻¹⁶ and an early concussion may put children at risk for later behavioral and cognitive problems.¹⁷ It is critical for the public health community to measure risks of concussions and their prevalence among adolescents accurately in order to better focus prevention and management efforts.

To date, most of the surveillance information about concussions has been conducted with samples of public school students. For example, in the National High School Sports-Related Injury Surveillance Study's High School Reporting Information Online (High School RIO), a common source of sports-related concussion data, 85% of participating high schools are public schools.¹⁸ Data from the US Department of Education have demonstrated, however, there are systematic differences between public and private schools, in terms of resources, socioeconomic status, student make-up, and location.¹⁹ Evidence also has suggested that the athletic experiences in private versus public schools can be different.²⁰ For example, some private schools mandate students participate in a sport or athletic activity.²¹ Although beneficial, this could also potentially increase exposure to injury and concussion. Private schools may also offer a variety of athletic options (for example, archery, crew, sailing, squash) not typically found in public schools.²¹ In addition, youth sports TBI and concussion state laws do not always apply to private school students.²²

There is a crucial gap in knowledge about the concussion experience of private high school students who play a sport or engage in a recreational activity. The purpose of this study is to explore the lifetime concussion prevalence, proportion of concussions that were sports-related, and concussions that occurred during school sports among students attending private high schools by sex, contact level of their primary sport, number of seasons played, and age of first concussion.

METHODS

Self-reported data were collected as part of a project from Pink Concussions, a non-profit organization whose mission is to improve pre-injury education and awareness and post-injury medical care for women and girls affected by TBI.²³ The project aimed to explore the experiences and attitudes toward

concussion among a convenience sample of private preparatory high school students. Eight schools from the New England Preparatory School Athletic Council (NEPSAC) were selected to participate in this project. These schools are located in Connecticut, Maine, Massachusetts, and Rhode Island. Two additional schools of similar size and socioeconomic status in New York were included but are not part of NEPSAC. Six of the 10 schools are day schools, 3 are boarding schools, and 1 school is a mix of day and boarding. All schools in the sample and in NEPSAC more widely have at least one full-time certified athletic trainer on staff. IRB approval was obtained from the Connecticut Children's Medical Center (CCMC IRB#18-018). An opt-out letter was sent to all parents in the 10 schools. The children of those parents who opted out were not given the opportunity to complete the survey. The findings and conclusions in this manuscript are those of the authors and do not necessarily represent the official position of the US Centers for Disease Control and Prevention.

Participants

Data were collected from 2122 male and female private high school students between April and May 2018. Seventy-five students (3.5%) were excluded from the final analysis because they did not report playing a sport or engaging in a recreational activity, for a final sample size of 2047.

Instrumentation

The survey questions for the analysis included:

- What is your primary sport?
- What level of sport do you play? (school-based, elite/premier, recreational)
- How many seasons of sports do you play a year?
- Have you ever had a concussion? (definition of concussion provided: "a concussion is a blow to the head followed by a variety of symptoms that may include any of the following: headache, dizziness, loss of balance, blurred vision, 'seeing stars,' feeling in a fog or slowed down, memory problems, poor concentration, nausea, or throwing up. Getting 'knocked out' or being unconscious does not always occur with a concussion.")
- How old were you when you sustained your first concussion?
- How many of your concussions were related to organized sports?
- Of your sports-related concussions, how many did you receive while playing for your school?

In addition to these questions, the survey asked the students to report their sex (male, female) and grade in school (freshman, sophomore, junior, senior). The

survey was field tested a year earlier with 365 students at the KING School for readability, reliability, and validity.

Procedure

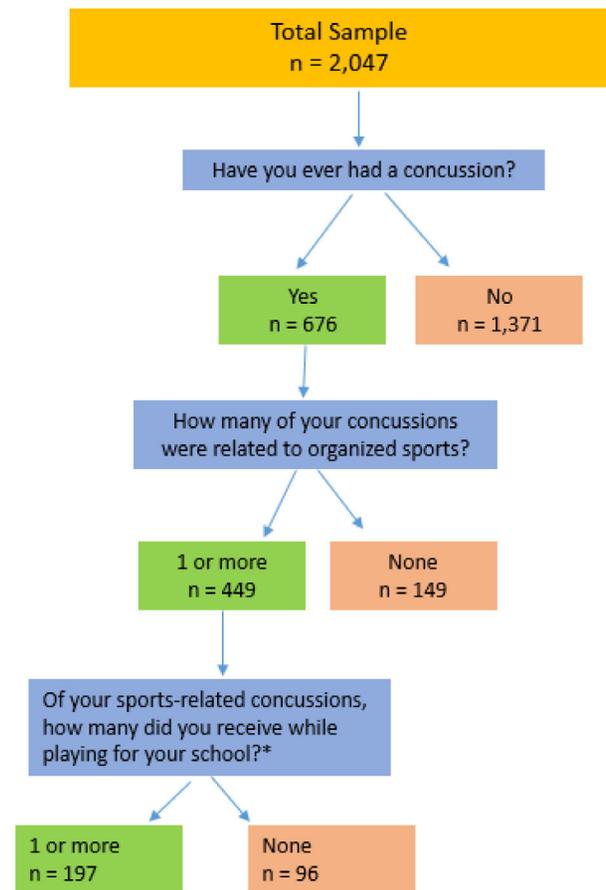
Students were asked if they were willing to complete an anonymous online survey during an advisory period on a school day. The student's advisor emailed the link to the survey at the beginning of the advisory period. Participation was voluntary and no incentives were offered. The survey took on average 3 minutes to complete. The average response rate across the 10 schools was 68% of total student enrolled in that academic year.

Data Analysis

Descriptive statistics for the study variables were computed. Concussion experience (ever having a concussion; number of sports-related concussions (0, 1, 2 or more); and number of school sports-related concussions (0, 1, 2 or more)) was stratified by sex of the student athlete, contact level of primary sport played, level of sport played (school sports only, elite/premier sports only, or recreation sport only), number of seasons of school sports played, and age of first concussion. The question assessing number of sports-related concussions was limited to those respondents who reported having ever experienced a concussion (676/2047, or 33.0% of sample) (see Figure 1 for flow-chart of questions and corresponding sample sizes). Seventy-eight (11.5%) of those respondents who reported ever having a concussion did not respond to the sports concussion question, for a total sub-sample of 598. An analysis (not shown) determined students who did not answer this question were not statistically significantly different than those who did in terms of contact level of sport, sex, type of sport played, or number of seasons of school sport played. The question assessing number of school sports-related concussion was limited to those respondents (1) who reported having ever experienced a sports-related concussion and (2) reported only playing school sports (N = 293/598 concussed student athletes who answered the sports-related concussion question). Seventeen respondents (5.5%) skipped this question.

Each primary sport listed by respondents was classified into a 3-level ordinal variable by level of contact based on the potential for physical contact between players and/or playing surface and intensity.²⁴⁻²⁷ The levels include "collision or contact sports" (such as football and soccer), "limited contact sports" (such as baseball and volleyball), and "non-contact sports" (such as track and field and tennis). Student athletes also indicated whether they played 1, 2, or 3 seasons of sports at school and/or an

Figure 1. Flow-Chart of Concussion-Related Questions and Samples Sizes



*Only asked of students who reported playing only school-based sports

elite/premier level of sport outside of school. Thirty-seven (of a total of 1352, or 2.7%) students reported playing multiple number of school sports seasons (for example, they reported playing both 1 and 2 seasons of school sports, or playing both 2 and 3 seasons of school sports). They were dropped from analyses assessing the impact of number of seasons of school sports played as it was unclear how many seasons they actually played. However, these students who were dropped from the analysis were no more likely to report having experienced a concussion than those who remained. To examine potential differences in concussion experience by level of sport (school, elite/premier, or recreation) played, the analytic sample was limited to those student athletes who selected only one level of sport (ie, those respondents who indicated they played both school sports and an elite/premier level sport were not included). Of the 37 dropped respondents, 19 (51.4%) from above were subsequently added back into the analysis of level of sport played as they played school sports exclusively (the remaining 18 also reported playing either elite/premier or recreation sports in addition

to multiple seasons of school sports). Again, these students who were dropped from the analysis were no more likely to report having experienced a concussion than those who remained.

Additionally, to determine whether there was an impact of the number of seasons of school sports played, we categorized those who played school sports into 1 season, 2 seasons, or 3 seasons. Finally, we examined the association between age of first concussion and number of sports-related concussions (no sports-related concussions, 1 sports-related concussion, or 2 or more sports-related concussions), and number of school sports-related concussions (no school sports-related concussion, 1 school sports-related concussion, or 2 or more school sports-related concussions). The analysis of the number of school sports-related concussions was restricted to those students who report playing school sports and those who reported sustaining at least one sports-related concussion ($N = 293$).

The statistical package SAS version 9.4 (Cary, NC) and IBM SPSS version 26 were. To determine whether concussion experience was associated with sex, contact level of primary sport, level of sport played, and number of seasons of school sports played, χ^2 tests or Fisher's exact tests (when comparisons included cell sizes <5) were conducted. To examine the association between concussion experience and age of first concussion, a one-way ANOVA test (or a non-parametric Welch's ANOVA) was conducted. When overall statistical significance occurred between groups, a proportions tests with a Bonferroni correction were applied for χ^2 or Fisher's exact tests while a Games-Howell post hoc test with a Bonferroni correction was applied to significant ANOVA tests, due to not meeting the homogeneity of variances assumption. Effect sizes were also computed for each χ^2 and ANOVA test using Cramer's V or partial Eta-square and interpreted in accordance with Cohen.²⁸ An r of .1 represents a small effect size, an r of .3 represents a medium effect size, and an r of .5 represents a large effect size.²⁸

Finally, to assess for any effect of clustering of the schools on the 3 outcomes, we performed an intra-cluster correlation investigation using a generalized linear mixed logistic regression model for the estimation of the covariance parameter for the correlation of school.²⁹⁻³¹ Also, a generalized linear mixed Poisson approach was used to check the consistency of the results. We found any observed school effect was low, ie, 1%-20% of the variation comes from the schools. Therefore, accounting for autocorrelation in our analyses was not necessary.

RESULTS

The sample was relatively evenly split between boys (47.8%) and girls (52.2%) and across the 4 high

school grades (Table 1). The students indicated that they played a large variety of sports. About 14.0% of student athletes played soccer as their primary sport, 10.2% played lacrosse, 9.4% played tennis, 7.8% played basketball, and smaller percentages played other sports. When asked at what level they play sports, 88.0% reported playing only school-based sports, 8.1% only played a premier/elite level of sport outside of school, and 3.8% only played at a recreational level. When looking further at the students who played only school-based sports, about one-quarter (26.0%) reported playing one season, 37.0% played 2 seasons, and 37.1% played 3 seasons.

Overall, one third (33.0%) of the students who played a sport or engaged in a recreational activity reported having experienced a concussion at some point in their lifetimes. Of these students, the mean age of first concussion was 9.5 (Table 2). Just over half of students (55.1%) who had sustained a concussion in their lifetime reported experiencing their first concussion between the ages of 10-15 while a smaller proportion (44.9%) sustained their first concussion before the age of 10. No students reported sustaining their first concussion after the age of 15. Sex ($p < .0001$), contact level of primary sport ($p < .0001$), level of sport played ($p = .04$), and number of seasons of school sports played ($p = .03$) were significantly associated with ever having had a concussion (Table 2). However, the practical significance of these effects were all low, ranging from a Cramer's V of 0.06 to 0.12. Post hoc analyses suggested that a greater proportion of boys than girls reported ever having had a concussion, a higher percentage of students who reported playing a contact sport as their primary sport reported having had a concussion compared to students who played a limited contact sport or a non-contact sport; and a lower percentage of students who played one season of school sports had sustained a concussion than students who played 2 seasons. After correcting for multiple comparisons, there were no statistically significant pair-wise differences in reporting ever having had a concussion by level of sport.

Of the students who reported ever experiencing a concussion, approximately three fourths reported that at least one concussion was sports-related (Table 1). About 4 in 10 (43.3%) had experienced 1 sports-related concussion and 31.8% experienced 2 or more sport-related concussions. In the bivariate analyses, sex ($p = .03$), contact level of primary sport played ($p < .0001$), level of sport played ($p = .04$), and age of first concussion ($p < .0001$) were significantly associated with the number of sports-related concussions experienced (Table 2). The Cramer's V for all of these tests were 0.21 or lower, indicating a small effect size. Post-hoc analyses suggested that a higher percentage of boys than girls reported experiencing

Table 1. Description of Sample and Self-Reported Characteristics

	Frequency	Percent
<i>Sex</i>		
Male	979	47.8
Female	1068	52.2
Total	2047	100.0
<i>Grade in school</i>		
Freshman	664	32.4
Sophomore	493	24.1
Junior	452	22.1
Senior	438	21.4
Total	2047	100.0
<i>Primary sport</i>		
Soccer	286	14.0
Lacrosse	208	10.2
Tennis	192	9.4
Basketball	159	7.8
Hockey	122	6.0
Crew	122	6.0
Cross Country	101	4.9
Squash	98	4.8
Volleyball	104	5.1
Baseball	79	3.9
Other	576	28.1
<i>Level of sports played*</i>		
School sport only [†]	1352	88.0
Premier/elite only	125	8.1
Recreation only	59	3.8
<i>How many seasons of school sports played[‡]</i>		
One season	346	26.0
Two seasons	493	37.0
Three seasons	494	37.1
<i>Ever experienced a concussion</i>		
Yes	676	33.0
No	1371	67.0
<i>Age of first concussion (years)^{§, ,¶}</i>		
0-4	43	6.7
5-9	247	38.2
10-15	356	55.1
<i>Number of concussions that were sports-related^{,¶, **}</i>		
None	149	24.9
1	259	43.3
2 or more	190	31.8
<i>Number of sports-related concussions sustained while playing for school^{††,‡‡,§§,¶¶}</i>		
None	96	32.8
1	139	47.4
2 or more	58	19.8

*Excludes students who indicated they played more than one level of sports, eg, those who played both school and elite/premier sports.

[†] Includes students who gave multiple responses to the question “how many seasons of school sports played” as the inability to interpret number of seasons did not affect the ability to determine they participated only in school sports.

[‡] Students who gave multiple responses to the question were excluded because we were unable to interpret their responses to the question.

[§] Question wording: How old were you when you think you sustained your first concussion?

^{||} Only includes students who answered “yes” to “have you ever had a concussion?”

[¶] 30 students who answered yes to “have you ever had a concussion?” did not answer this question.

[#] Question wording: How many of your concussions were related to organized sports (ie, team sports)?

^{**} 78 students (11.5%) who answered yes to “have you ever had a concussion?” did not answer this question.

^{††} Question wording: of your sports-related concussions, how many did you receive while playing for your school?

^{‡‡} Only includes students who indicated they had received at least one sports-related concussion in the “how many of your concussions were related to organized sports (ie, sports teams)?” question.

^{§§} 17 students (5.5%) who answered affirmed that they had at least one sports-related question did not answer this question.

^{¶¶} Limited to students who reported playing only school sports (any number of seasons).

Table 2. Bivariate Associations of Sport-Related, and School Sport-Related Concussion Experience, by Sex, Contact Level of Primary Sport, Number of Seasons of Sport Played, Level of Sport Played, and Age of First Concussion

	Ever experienced a concussion (n = 2,047)*						Number of sports-related concussions (n = 598)*, †						Effect size (Cramer's V or partial Eta-square)			
	Yes		No		Test statistic (χ ² or one-way ANOVA)	p-value	Effect size (Cramer's V)	None		One		Two or more		Test statistic (χ ² or one-way ANOVA)	p-value	
	N	%	N	%				N	%	N	%	N				%
Sex					27.46	<.0001	0.12						7.06	.03	0.11	
Male	379	38.7	600	61.3				76	22.5	140	41.4	122	36.1			
Female	297	27.8	771	72.2				73	28.1	119	45.8	68	26.2			
Contact level of primary sport					29.81	<.0001	0.12						51.25	<.0001	0.21	
Contact	367	39.1 [¶]	572	60.9 [¶]				49	14.8 [¶]	152	45.9	130	39.3 [¶]			
Limited contact	136	29.6	324	70.4				36	30.0	54	45.0	30	25.0			
Non-contact	173	26.7	475	73.3				64	43.5	53	36.1	30	20.4			
Level of sport played					6.41	.04	0.06						10.07	.04	0.11	
School only [#]	428	31.7	924	68.3				81	21.7 ^{**}	171	45.7	122	32.6			
Elite only	51	40.8	74	59.2				14	33.3	18	42.9	10	23.8			
Recreation only	14	23.7	45	76.3				7	50.0	6	42.9	1	7.1			
Number of seasons of school sports played ^{††}					7.12	.03	0.07						3.68	.45	0.07	
One	90	26.0 ^{‡‡}	256	74.0 ^{‡‡}				20	26.0	34	44.2	23	29.9			
Two	170	34.5	323	65.5				27	18.0	76	50.7	47	31.3			
Three	161	32.6	333	67.4				33	23.2	59	41.6	50	35.2			
Age of first concussion					N/A	N/A	N/A	Mean	9.3	SD	3.2	Mean	10.2 ^{¶¶}	SD	2.6	
								Mean	10.2 ^{¶¶}	SD	2.6	Mean	8.9	SD	2.6	

Table 2. Continued

	Number of sports-related concussions received while playing for school (n = 293) ^{††§}						Test statistic (χ^2 or one-way ANOVA)	p-value	Effect size (Cramer's V or partial Eta-square)
	None		One		Two or more				
	N	%	N	%	N	%			
Sex									
Male	57	35.6	67	41.9	36	22.5	4.48	.11	0.12
Female	39	29.3	72	54.1	22	16.5			
Contact level of primary sport									
Contact	61	33.9	81	45.0	38	21.1	3.18	.53	0.07
Limited contact	21	36.8	26	45.6	10	17.5			
Non-contact	14	25.0	32	57.1	10	17.9			
Level of sport played									
School only [#]	—	—	—	—	—	—	N/A	N/A	N/A
Elite only	—	—	—	—	—	—			
Recreation only	—	—	—	—	—	—			
Number of seasons of school sports played ^{††}									
One	19	33.3	28	49.1	10	17.5	1.47	.83	0.05
Two	38	30.9	62	50.4	23	18.7			
Three	38	34.9	47	43.1	24	22.0			
Age of first concussion	Mean	SD	Mean	SD	Mean	SD	8.07	.0005	0.05
	9.4	2.5	10.5 ^{§§}	2.4	9.4	2.5			

* Only includes students who indicated that they had a primary sport.

† Only includes students who answered "yes" to "Have you ever had a concussion?" Data are missing from 11.5% (n = 78) of respondents.

‡ Includes the students who indicated they exclusively played school sports only (any number of seasons).

§ Only includes students who answered indicated that had at least one sports-related concussion. Data are missing from 5.5% (n = 17) of respondents.

|| Significantly different than the other category at p < .05 level.

¶ Significantly different than the both other category at p < .05 level.

Includes students who indicated they played more than one category of school sports, e.g. both 1 and 2 seasons of school sports.

** Significantly different than the last category at p < .05 level.

†† Students who gave multiple responses to the question "how many seasons of school sports played?" were excluded because we were unable to interpret their responses to the question.

‡‡ Significantly different than the second category at p < .05 level.

§§ Significantly different than the none category at p < .05 level.

2 or more sports-related concussions, a higher percentage of students who played contact sports as their primary sports reported experiencing 2 or more sports-related concussions than students who played limited contact or non-contact sports, and a smaller percentage of student athletes who played only school sports reported no sports-related concussions than student athletes who played only recreation sports. Post hoc tests also suggested that the mean age among those with 1 concussion was significantly higher compared to those with no concussions and those with 2 or more concussions; however, the overall effect size was small (partial Eta-square = 0.04). Number of seasons of school sports played among students who played school sports ($p = .45$) was not significantly associated with the number of sports-related concussions.

Among students who self-reported they sustained at least one sports-related concussion, about half were while playing a school sport (Table 1). Nearly 4 in 10 (39.3%) reported one school sports-related concussion while 15.5% reported 2 or more school sports-related concussions. Sex ($p = .11$), contact level of primary sport ($p = .53$), and number of seasons of school sports played ($p = .83$) were not significantly associated with experiencing a sport-related concussion while playing for their school (Table 2). Age of first concussion was statistically significantly associated with having sustained a concussion while playing a school sport ($p = .0005$) but the effect size was small (partial Eta-square = 0.05). Post hoc analyses suggested the mean age among those with one school sports-related concussion was higher compared to those with no school sports-related concussions.

DISCUSSION

Most prior descriptive epidemiological surveillance of sports- and recreation-related concussions in youth has been conducted among public school students,³² but this study demonstrated private high school student athletes are also at risk of experiencing concussions. A 2018 study of high school students reported that about 1 in 5 who played on at least 1 sports team had sustained a concussion in the past 12 months.⁹ Out of 2047 high school student athletes in this sample, one third reported a concussion history. Of note, however, the composition of sports in this sample is different than what is seen in most public and private high schools. For example, football, the most commonly played sport among high school boys, was not even ranked in the top 10 for the primary sport played among student athletes in this sample, while other traditionally less popular sports, such as crew and squash, were more popular in this setting.³³ The popularity of these sports is likely attributable to

the unique setting of these schools in this particular region.

This study also reiterated certain factors associated with a student having sustained a concussion in their lifetime. Male students,⁶⁻⁸ those who played contact sports,³⁴ and students who played 2 seasons of sports at school (ie, more exposure)^{9,35} were more likely to report a concussion in their lifetime than other students.

The median age of first concussion in this sample of private high school student athletes was 9.5. A study conducted by Schmidt et al.³⁶ reported individuals who reported their first concussion during childhood (less than 10 years old) doubled the risk of sustaining a subsequent concussion compared to individuals who reported their first concussion during adolescence (10-18 years old). Due to an increased susceptibility for subsequent concussions, and often more severe outcomes after one has sustained an initial concussion, it is important that any youth with a suspected concussion be removed from play and evaluated by a health care provider and then follow return-to-learn and return-to-play protocols.

This study suggests private secondary schools require targeted prevention efforts. The Centers for Disease Control and Prevention (CDC) introduced a concussion education campaign in 2010 called CDC HEADS UP. This campaign provides free information and resources targeted specifically to youth athletes, parents, coaches, schools, and health care providers (www.cdc.gov/headsup). Athletic trainers at private schools can encourage coaches and parents to take the free online training and provide customizable fact sheets to student athletes that outline what they should do if they suspect they have sustained a concussion. In a sample of college/university athletes, Guskiewicz et al.³⁷ suggested athletes with a history of concussions were more likely to experience a concussion in the future than athletes without such a history. Similarly, there is some evidence that a prior history of a TBI is a risk factor for a subsequent concussion in children.³⁸ It is therefore important to intervene earlier in athletic careers to prevent incident and additional concussions as it is known that children's outcomes are more severe and children take longer to recover from concussions than older adolescents and adults.^{13,14,39,40}

Future research should expand upon this current study by surveying the concussion experience of private high school student athletes in different regions of the country to determine if the results reported here are generalizable to different parts of the United States. A direct comparison of the concussion risk among private versus public high school student athletes can also be pursued. Finally, longitudinal studies are warranted to determine if outcomes vary by sex, contact level, or level of sport played when concussion was sustained.

Limitations

The data from this survey come from a convenience sample of private high school students in a cluster of schools in New England and New York. Therefore, the results may not be generalizable to other private high school students, and similar surveys should be conducted in different regions of the United States. Concussion experience was self-reported and may be subject to recall bias. For example, relatively recent TBIs and TBIs of greater severity may be more likely to be recalled. In addition, reported concussions were not validated, for example, through medical records or validated symptom inventory. Similarly, some of the wording of the questions left room for interpretation among the students. For example, the question “How many seasons of sports do you play a year?” might have been interpreted as the number of seasons of sports played during the school year or in a year on average. This may have slightly affected the findings in indeterminable ways. There was also no way to determine whether students might have played more than one sport in a season, or multiple seasons and/or level of one sport, which might have affected their concussion risk. Students who played both school-based sports and elite/premier sports, for example, may be at an increased risk of concussion than students who play one level of sport. This question should be examined in future research.

Additionally, it is important to consider how private schools in this particular sample may be different than public high schools and other private high schools in ways that influence concussion reporting. The schools in this study are a mixture of day schools and boarding schools. In addition, schools in this study have at least one full-time athletic trainer and several have 2, all of whom have been at the schools for at least 7 years. A large study of public and private high schools found that 35% of schools have full-time athletic training services and an additional 30% have part-time services.⁴¹ Studies have further suggested the presence of athletic trainers at a school can influence - specifically increase - concussion reporting among students.^{32,42} Studies have suggested that athletic trainers may be better at identifying potential symptoms of a concussion after an injury has occurred than coaches.⁴³ Additionally, students attending schools with athletic trainers are also more likely to have a greater level of concussion knowledge⁴⁴ and generally have access to a higher level of resources.⁴⁵ Furthermore, each school in the sample has had a concussion management policy in place for at least 6 years, and a concussion education component for students, coaches, and parents. Thus, in this study students may have been particularly sensitized to the concussion issue and aware of the importance of reporting concussions. The approach to concussion reporting, the presence of full-time athletic trainers,

and the attention to injury among this sample of 10 schools represents the best case scenario and is likely not representative of American high schools generally.⁴⁶ Moreover, students at the schools in this sample are required to play at least one sport or recreational activity; indeed, about 50% of the students in this sample played 2 or 3 seasons of school sports, and may be at an increased risk for exposure to head impacts. For these reasons, the lifetime concussion prevalence in this sample may neither be generalizable nor comparable to that seen in other studies.

Finally, it is important to note while many of the variables in this study were statistically significantly related to having sustained a concussion, none showed a practically significant relationship as judged by their effect sizes. This fact should provide context when interpreting the relationships between sex, contact level of sport played, and level of sport played with reported concussions among these student athletes.

IMPLICATIONS FOR SCHOOL HEALTH

Despite playing a different composition of high school sports, private preparatory high school student athletes, just as other student athletes, are at risk of sustaining concussions. It is important to encourage these student athletes to report their potential injuries to their coaches, parents, and health care providers in order to receive prompt and appropriate treatment to lessen possible long-term consequences. Concussion prevention strategies particular to the private school setting and the less common sports seen in this population (for example crew, squash) may be needed.

In addition, the findings from this report suggest a need for ongoing educational initiatives addressing concussion risk associated with school-based sports. Previous research has shown that more effort needs to be put into developing strategies to improve concussion-related knowledge, attitudes, and behaviors.⁴⁷ Our findings have a number of implications for policy and practice regarding school health. Private schools may consider taking the following actions in bullets below to help prevent the occurrence of concussion among their students:

- Develop messages informing student athletes about the risks of concussion. While studies have shown that youth and high school students have a high level of awareness and knowledge about concussion,^{48,49} adolescent athletes are also likely to “under-appreciate” the risk and seriousness of concussion.^{50,51} It is thus important for students to recognize the detrimental effects that concussions can have on their physical, academic, emotional, and social health. Private school athletic programs may consider adopting a formalized concussion education

program for their students, such as the CDC HEADS UP initiative.⁵²

- Advocate for coaches and parents to encourage student athletes to follow the rules of play. Previous research has found that a substantial proportion of sports-related injuries in high school athletes are due to illegal activity; this proportion is especially high in soccer and often results in concussions.⁵³ It is therefore important that students are mandated to follow the rules of their sport and that those coaching and cheering on these athletes support sportsmanship in order to promote player safety.
- Encourage referees to enforce the rules for their sport. Referees and other sports officials help maintain standards of play during athletic events.⁵⁴ Because a number of sports-related injuries are due to activities that are against the rules,⁵³ referees who enforce the rules of their sports may reduce the possibility of such injuries.⁵⁵

All these actions may help to decrease the incidence and severity of concussions among private high school students.

Human Subjects Approval Statement

This research was reviewed and approved by the Institutional Review Board at the Connecticut Children's Medical Center.

Conflict of Interest

All authors of this article declare they have no conflicts of interest.

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