What’s known on this subject: Data from several states that have implemented protective eyewear mandates at the scholastic level have shown a substantial reduction in eye injuries. However, there are no studies that critically evaluate the effectiveness of protective eyewear in girls’ field hockey.

What this study adds: Data collected from regional/national high school sports injury surveillance databases by certified athletic trainers has resulted in the largest prospective national study examining the effectiveness of mandatory protective eyewear in reducing head, eye/orbital, concussive, and facial injuries performed to date.

Effectiveness of Protective Eyewear in Reducing Eye Injuries Among High School Field Hockey Players

OBJECTIVE: To determine if injury rates differ among high school field hockey players in states that mandated protective eyewear (MPE) versus states with no protective eyewear mandate (no MPE).

METHODS: We analyzed field hockey exposure and injury data collected over the 2009–2010 and 2010–2011 scholastic seasons from national and regional databases.

RESULTS: Incidence of all head and face injuries (including eye injuries, concussion) was significantly higher in no-MPE states compared with MPE states, 0.69 vs 0.47 injuries per 1000 athletic exposures (incidence rate ratio [IRR] 1.47; 95% confidence interval [CI]: 1.04–2.15, P = .048). Players in the no-MPE group had a 5.33-fold higher risk of eye injury than players in the MPE group (IRR 5.33; 95% CI: 0.71–39.25, P = .104). There was no significant difference in concussion rates for the 2 groups (IRR 1.04; 95% CI: 0.63–1.75, P = .857). A larger percentage of injuries sustained by athletes in the no-MPE group required >10 days to return to activity (32%) compared with athletes in the MPE group (17%), but this difference did not reach statistical significance (P = .060).

CONCLUSIONS: Among high school field hockey players, playing in a no-MPE state results in a statistically significant higher incidence of head and face injuries versus playing in an MPE state. Concussion rates among players in MPE and no-MPE states were similar, indicating that addition of protective eyewear did not result in more player-player contact injuries, challenging a perception in contact/collision sports that increased protective equipment yields increased injury rates. Pediatrics 2012;130:1069–1075.

KEY WORDS girls’ field hockey, eye injuries, protective eyewear, injury prevention, injury surveillance

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AFFILIATIONS girls’ field hockey, eye injuries, protective eyewear, injury prevention, injury surveillance

ABBREVIATIONS AE—athletic exposure AT—certified athletic trainer CI—confidence interval HS—high school IRR—incidence rate ratio MPE—mandated protective eyewear

Dr Kriz conceptualized and designed the study, collected and analyzed data from the 2 databases, drafted the initial manuscript, and approved the final manuscript as submitted; Dr Comstock designed the data collection instruments, coordinated and supervised data collection at one of the 2 sites, assisted with study design, reviewed and revised the manuscript, and approved the final manuscript as submitted; Dr Zurakowski carried out the statistical analyses, contributed tables and figures, reviewed and revised the manuscript, and approved the final manuscript as submitted; J. Almquist and C. Collins designed the data collection instruments, coordinated and supervised data collection at one of the 2 sites, and approved the final manuscript as submitted.

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(Continued on last page)
Field hockey is among the most frequently played team sports in the world, second only to soccer. Epidemiological studies demonstrate that field hockey injuries are numerous and can be serious: in a recent National Collegiate Athletic Association study, 25% of field hockey game injuries involved the head and neck. Most serious injuries result from being struck by the stick or ball. Although eye injuries are infrequent, they tend to be severe and, on occasion, catastrophic. One in 25 field hockey players reportedly will experience an eye injury over an 8-year career.

Over the past 2 decades, several changes to equipment, playing surfaces, and styles of play have potentially increased the risk and magnitude of field hockey injuries: (1) advances in stick construction have allowed players to generate more power and velocity, with ball speeds $\geq 50$ mph achieved by high school (HS) girls and nearly 100 mph by elite players; (2) artificial turf creates a smoother, faster playing surface; and (3) the ball is being elevated off the field more frequently. Additionally, there has been a 29% increase in participation at the HS level from 1990 to 2010. Despite policy and position statements that strongly recommend certified protective eyewear from organizations including the American Academy of Ophthalmology, the American Academy of Pediatrics, the International Federation of Sports Medicine, the American Optometric Association, the US Department of Health and Human Services, Prevent Blindness America, and the Coalition To Prevent Sports Eye Injuries, the governing body of field hockey in the United States (US Field Hockey) does not mandate protective eyewear use for field hockey players. After the initiation of this study in 2009 and effective with the 2011–2012 scholastic season, the National Federation of State High School Associations has mandated that HS field hockey players wear protective eyewear meeting the current American Society for Testing and Materials standard for field hockey.

Currently, field hockey is a sanctioned HS sport in 19 US states with $\geq 63,000$ girls participating annually. At the initiation of this study in fall 2009, only 6 state interscholastic athletic associations mandated protective eyewear (MPE) for all HS field hockey players (Connecticut, Maine, Massachusetts, New Hampshire, New York, and Rhode Island). This disparity among states regarding protective eyewear mandates before the 2011–2012 HS season provided a novel opportunity to investigate whether risk of eye injury for HS field hockey players differs in states with MPE compared with states with no protective eyewear mandate.

**METHODS**

The primary objective of this study was to examine whether risk of eye/orbital injury during practices and games differs for HS field hockey players in states with MPE compared with players in states with no MPE. Secondary objectives included examining differences between cohorts for (1) all head, face, eye/orbital, and concussive injuries; (2) concussive injuries only; (3) head and face injuries only (excluding eye/orbital and concussive injury); and (4) all injuries resulting in delayed return to activity (time loss $\geq 21$ days and/or medical disqualification for remainder of season).

A prospective cohort study was conducted during 2 seasons of play (fall 2009, fall 2010), immediately before a national protective eyewear mandate in field hockey exercised by the NFHS, effective fall 2011. The study population was HS field hockey players. Cohorts were defined by their participation in a state interscholastic league that either MPE or had no protective eyewear mandate (no MPE). Inclusion criteria were the following: HS field hockey players; male or female; play occurring during the HS-sanctioned season; and participating HS covered by a certified athletic trainer (AT). Exclusion criteria were the following: injuries sustained during field hockey play unrelated to practice or competition, off-season field hockey practices or competitions, or activity unrelated to field hockey practices or games.

Given the prospective nature of the study design, no intervention of any kind was performed, no personal data were collected, and thus informed consent was not obtained from study participants. Institutional review board approval was granted from Rhode Island Hospital for the study.

The injury surveillance systems used in this study included: (1) High School Reporting Information Online, an Internet-based data collection tool developed by one of the authors (R.D.C.) to track epidemiological data used in the National High School Sports-Related Injury Surveillance Study, and (2) Fairfax County (Virginia) Public Schools Athletic Training Program, a large public school system with 25 member HSs. Fairfax County Public Schools used a district-mandated electronic medical record program for injury surveillance (J.L.A.). ATs collected field hockey–related athletic exposure (AE) and injury information throughout the study period, submitting reports either daily or weekly. Included in the data collection was whether MPE was in effect in the injured player’s state of HS attendance. An AE was defined as 1 athlete participating in 1 practice or competition. A reportable injury was defined as one that (1) occurred as a result of an organized HS athletic practice or
competition, (2) required medical attention from a team AT or physician, and (3) resulted in restriction or alteration of the athlete's participation status. For each injury, the AT completed a detailed report that included the date of injury, type of exposure (eg, practice versus competition), characteristics of the injury (eg, body site, diagnosis, severity, time loss), and circumstances leading to the injury (eg, mechanism, specific activity at time of injury). Data sets from both databases were combined, and the authors (R.D.C., J.L.A.) regularly maintained and monitored them to maximize compliance and data quality.

Incidence rate ratios (IRRs) for each of the injury outcomes were estimated with 95% confidence intervals (CIs) by using Poisson log-linear regression. The Z test was used to determine whether the IRR differed from 1. Time in days to return to field hockey after injury was compared by using 6 time interval categories with groups compared by \( \chi^2 \). We also evaluated whether athletes in the MPE group were less likely to require >10 days to return to field hockey compared with those in the no-MPE group by using logistic regression analysis with the likelihood ratio test used to assess significance. Data analysis was performed by using SPSS version 19.0 (SPSS Inc./IBM, Chicago, IL). Two-tailed values of \( P < .05 \) were considered statistically significant.

**RESULTS**

One hundred eighty HSs participated in the study. HS field hockey players sustained 212 eye/orbital, head, and facial injuries during 329,601 AEs. Table 1 summarizes the study population characteristics. Players from 14 of the 19 states that sanction HS field hockey were represented. The proportion of schools participating from states with protective eyewear mandates was similar to the proportion of states that had protective eyewear mandates during the study period (39/141, 28% and 6/19, 32%, respectively).

Thirty-one injuries were reported in the MPE group in 66,286 AEs, and 181 injuries were reported in the no-MPE group in 263,315 AEs. Cohort-specific injury rates and the corresponding IRRs for total head and face injuries (including eye/orbital and concussion), concussive injuries, head/facial injuries (excluding eye/orbital and concussion), eye/orbital injuries only, and severe injuries are summarized in Table 2. Injury rates were lower in the MPE group compared with the no-MPE group for all injury subcategories, although our sample size did not provide enough power to demonstrate statistical significance.

Among total head and face injuries including eye/orbital and concussions, the IRR comparing the MPE and no-MPE groups was 1.47 (95% CI: 1.04–2.15, \( P = .048 \)). The incidence of total head and face injuries was 0.69 injuries per 1000 AEs in the no-MPE group compared with 0.47 injuries per 1000 AEs in the MPE group, resulting in a 32% lower injury rate in the MPE group. There was no difference in concussion rates for the 2 groups (IRR 1.04; 95% CI: 0.63–1.75, \( P = .857 \)).

Only 1 eye/orbital injury was recorded in the MPE group: a corneal abrasion of the right eye in a junior varsity forward that was shooting during practice. This injury resulted from contact with a stick; the injured player was wearing off-the-shelf protective eyewear at the time of injury. The athlete returned to activity within 3 to 6 days. In contrast, 21 eye/orbital injuries were recorded in the no-MPE group. Of these 21 injuries, 4 (14%) resulted in time loss >21 days; none resulted in medical disqualification for the season. The eye/orbital injury rate for the MPE group compared with the no-MPE group was 0.015/1000 AEs versus 0.080/1000 AEs, respectively; an 80% lower injury rate in the MPE group. Players in the no-MPE group had a 5.33-fold higher risk of eye injury than players in the MPE group (95% CI: 0.71–39.25). However, given the small numbers of injuries, this did not reach statistical significance (\( P = .104 \)).

Severe injuries were defined in this study as those that kept the athlete from activity >21 days after eye, head, or facial injury and/or resulted in medical disqualification for the remainder of the season. There were 26 severe injuries in the no-MPE group and 1 severe injury in the MPE group. Severe injury rates for the MPE and no-MPE groups were 0.015 and 0.1 per 1000 AEs, respectively. Players in the no-MPE group had a 6.67-fold increased risk of severe injuries compared with players in the MPE group which trended toward but did not reach statistical significance (95% CI: 0.89–47.62, \( P = .065 \)). Of the 27 injuries resulting in delayed return to activity, 14 (51.9%) were concussions, 7 (25.9%) were general trauma/contusion, 5 (18.5%) were fractures, and 1 (3.7%) was a laceration. The single severe injury in the MPE group was a fracture involving the mouth and teeth that resulted from ball contact.

Figure 1 summarizes the percentage of injuries in the MPE and no-MPE groups on the basis of time to return to activity. Seventeen percent of those injured in the MPE group took >10 days to return to field hockey compared with 32% in the no-MPE group. Logistic regression indicated that the likelihood of requiring >10 days to return to field hockey after injury resulted in a trend that approached statistical significance (likelihood ratio test = 3.52 on 1 degree of freedom, \( P = .060 \)), suggesting that MPE may indeed be associated with a shorter time to return to field hockey because
this significance level was close to the criterion of \( P < .05 \).

Table 3 summarizes the injury mechanisms for eye, head, and facial injuries evaluated in the study. Of the 212 eye/orbital, head, and facial injuries, 45.7% involved the head or face (excluding concussion and eye/orbital injuries), 43.9% were concussive injuries, and 10.4% were eye/orbital injuries.

DISCUSSION

To our knowledge, this study is the first prospective cohort study to use injury surveillance to investigate the effectiveness of MPE in reducing rates and severity of eye injuries in HS field hockey players. Our study demonstrates that MPE confers a reduced total head and face injury rate of 32% and a reduced eye/orbital injury rate of 80%. In addition, HS field hockey players participating in states with no MPE had a greater than sixfold increased risk of delayed return to activity from injury compared with players from MPE states. A noteworthy finding was that 14% (1 in 7) eye/orbital injuries sustained in the no-MPE group resulted in time loss of 21 days.

Injury rates for all eye/orbital, head/face, and concussive injuries were lower in the MPE group compared with the no-MPE group; however, only total head and face injury rates (including eye/orbital and concussions) between the 2 groups achieved statistical significance. Nonetheless, this result lends additional evidence to previous study findings that, for female athletes, as the amount of required protective equipment increases, injury rates decrease.\(^{17}\) Because injury rates for head/face and concussive injuries were lower in the MPE group compared with the no-MPE group, our findings indicate that protective eyewear affords direct and indirect protection to other head/facial areas from stick and ball contact that would otherwise be sustained in the absence of eye/orbital protection.

Our data indicate that injuries to eye orbits, eye globes, eyebrows, and eyelids were completely eliminated in the MPE group. These findings are concordant with a recent study by Lincoln et al\(^{18}\) in female HS lacrosse players, which also demonstrated a virtual elimination of the aforementioned eye/orbital injuries after mandated use of...
eyewear. The single eye injury recorded in our study’s MPE group was a superficial corneal abrasion that resulted in the athlete’s return to activity in 3 to 6 days.

Regarding player-player contact injuries, the percentage of injuries caused by this mechanism was the same in both the MPE and no-MPE groups (19.3%). Opponents of protective eyewear mandates have cited concern that protective eyewear obscures peripheral vision and can lead to more aggressive play, consequently increasing the incidence of player-player contact injuries. Our study failed to demonstrate this association.

No catastrophic injuries were recorded during our 2-season study period. In the United States, the National Center for Catastrophic Sports Injury Research has compiled data regarding HS direct catastrophic injuries (direct being defined as “injuries resulting directly from participation in the skills of the sport”) since 1982.19 The overall incidence of nonfatal direct catastrophic injuries in female HS field hockey players during this time period is 0.19 per 100,000 participants: the second highest of any female HS sport compiled by the National Center for Catastrophic Sports Injury Research. This equates to 1 such injury per 526,316 participants. Because time-based exposure metrics (eg, injuries per 1000 AEs) have replaced player-based exposures (eg, injuries per 100,000 participants) in injury surveillance studies, it would be difficult to calculate how many seasons of injury data would have to be collected to capture 1 catastrophic injury. Assuming that the HS field hockey season has remained fairly consistent between 1982 and 2010 in regard to the number of player exposures (practices and competitions) over the course of a given season, and knowing that 63,000 female athletes currently participate each year in HS field hockey, it is possible to speculate that, given an injury incidence rate of 0.19 per 100,000 participants, 1 catastrophic injury occurs in HS field hockey every 8.3 seasons.

Our study provides important epidemiological data regarding concussion rates in HS field hockey, a sport often excluded from large, national epidemiological studies because of lower participation rates compared with girls’ sports such as soccer, basketball, and volleyball. The overall concussion rate for both MPE and no-MPE groups was 0.28 injuries per 1000 AEs. Although it is often difficult to compare concussion injury rates across studies and time periods because of variables such as improved awareness, recognition, and diagnostic evaluation, previous studies of HS female athletes have shown the following concussion rates (per 1000 AEs): 0.36 injuries (soccer), 0.21 injuries (basketball), 0.10 to 0.21 injuries (lacrosse), 0.07 injuries (softball), and 0.05 injuries (volleyball).20–22 With the inclusion of our data, field hockey currently has the second-highest concussion rate among female HS sports for which concussion injury data are recorded. Moreover, because the concussion rates for MPE and no-MPE groups were similar (0.27 and 0.28 per 1000 AEs, respectively), these results indicate that the addition of protective eyewear did not result in more player-player contact injuries, challenging a commonly held perception in contact/collision sports that increased protective equipment yields increased injury rates, known as a “gladiator effect.”23

There were several limitations to our study. Given the established state mandates for protective eyewear that were in existence during the 2009–2010 and 2010–2011 seasons, we were unable to conduct a randomized study because enrollment in MPE and no-MPE groups was predetermined.

Additionally, while our power analysis indicated 80% power for detecting differences in injury rates between MPE and no-MPE groups with respect to total injuries, differences between MPE and no-MPE groups with respect to specific injury subcategories did not attain statistical significance because of small event rates in the MPE group, although rates were all lower among athletes having eyewear protection and several analyses demonstrated trends toward statistical significance.

Additionally, only schools with ATs were eligible to participate. Consequently, our results may not be generalizable to all schools in the United States. Another potential limitation was that injuries were categorized by principal body part (eg, head/face, eye/orbit, and nose). It

### Table 3: Injury Mechanisms for Eye, Head, and Facial Injuries

<table>
<thead>
<tr>
<th>Injury Mechanism</th>
<th>% of Total Injuries</th>
<th>No. of Injuries</th>
<th>% of MPE Injuries</th>
<th>No. of MPE Injuries</th>
<th>% of No-MPE Injuries</th>
<th>No. of Injuries</th>
<th>% of MPE Injuries</th>
<th>No. of No-MPE Injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact with ball</td>
<td>36.3</td>
<td>11</td>
<td>35.5</td>
<td>66</td>
<td>36.5</td>
<td>31</td>
<td>35.5</td>
<td>66</td>
</tr>
<tr>
<td>Contact with stick</td>
<td>30.7</td>
<td>11</td>
<td>35.5</td>
<td>54</td>
<td>29.8</td>
<td>3</td>
<td>19.3</td>
<td>35</td>
</tr>
<tr>
<td>Contact with player</td>
<td>19.3</td>
<td>6</td>
<td>19.3</td>
<td>35</td>
<td>19.3</td>
<td>3</td>
<td>9.7</td>
<td>5</td>
</tr>
<tr>
<td>Contact with ground</td>
<td>3.8</td>
<td>3</td>
<td>9.7</td>
<td>5</td>
<td>2.8</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Contact with goal</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.6</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Missing data</td>
<td>9.4</td>
<td>0</td>
<td>0</td>
<td>20</td>
<td>11.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>31</td>
<td>100</td>
<td>181</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
is possible that some inaccurate identification of injury location may have occurred given the close proximity of these facial structures. However, this is more likely to have resulted in underrepresentation rather than overrepresentation of eye/orbital injuries in the databases because eye/orbital injuries were included only if ATs commented on this specific area of injury in their data collection or comments section. Finally, our injury and exposure data did capture HS male field hockey players, although the overall participation rates of male players were <1% of the population for which data were collected. Nonetheless, the study results are not exclusively representative of female HS field hockey players. Despite these limitations, our study compiled data from 2 large regional and national injury surveillance databases before the implementation of a national protective eyewear mandate in HS girls’ field hockey, resulting in the largest prospective national study examining the effectiveness of MPE in reducing head, eye/orbital, concussive, and facial injuries performed to date.

CONCLUSIONS

Among HS field hockey players, playing in a state with no MPE results in a statistically significant higher incidence of head and face injuries compared with playing in a state with MPE. The addition of protective eye wear did not result in a higher incidence of concussions or other player-player contact injuries, challenging an unfounded perception in contact/collision sports that increased protective equipment yields increased injury rates. Our study supports future efforts to evaluate the effectiveness of protective eyewear in HS field hockey players in reducing eye injury rates before and after implementation of a national protective eyewear mandate, as well as performance of clinical studies in collegiate and national team field hockey players to determine whether the risk of eye injuries for these additional 5000 female athletes is reduced by the provision of protective eyewear for all field hockey–related activity.

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(Continued from first page)
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