an estimated 300,000 sport-related traumatic brain injuries, predominantly concussions, occur annually in the United States. Sports are second only to motor vehicle crashes as the leading cause of traumatic brain injury among people aged 15 to 24 years. In fact, for young people ages 15 to 24 years, sports are second only to motor vehicle crashes as the leading cause of traumatic brain injury among people aged 15 to 24 years. In high school sports played by both sexes, girls sustained a higher rate of concussions, and concussions represented a greater proportion of total injuries than in boys. In all sports, collegiate athletes had higher rates of concussion than high school athletes, but concussions represented a greater proportion of all injuries among high school athletes.

Conclusions: Sport-related injury surveillance systems can provide scientific data to drive targeted injury-prevention projects. Developing effective sport-related concussion preventive measures depends upon increasing our knowledge of concussion rates, patterns, and risk factors.

Key Words: epidemiology, injury surveillance, sex differences, traumatic brain injury
groups\textsuperscript{14–16} comparing concussion incidence and recovery in high school and collegiate athletes focused primarily on football, with minor consideration given to other male sports or to female sports. No authors to date have evaluated concussion rates for multiple sports among high school and collegiate athletes using directly comparable, nationally representative data.

Our purpose was to investigate the epidemiology of concussions in a nationally representative sample of high school athletes and to compare rates of concussion among high school and collegiate athletes.

METHODS

In the 2005–2006 High School Sports-Related Injury Surveillance Study, Reporting Information Online (RIO), an Internet-based surveillance system, was used to collect injury and exposure data for athletes participating in 9 US high school sports.\textsuperscript{18–20} The sports of interest were boys’ football, soccer, basketball, wrestling, and baseball and girls’ soccer, volleyball, basketball, and softball. All high schools with 1 or more NATA-affiliated high school certified athletic trainers (ATs) with a valid e-mail address were invited to participate (n = 4120). Schools with ATs agreeing to participate as data reporters (n = 425) were categorized into 8 sampling strata based on US census geographic regions\textsuperscript{21} and school size (enrollment ≤1000 or >1000). A simple random sample was then used to select schools from each sampling strata to achieve a nationally representative sample of 100 schools.

Weekly throughout the study period, ATs from participating schools logged onto the High School RIO Web site using a unique study ID number to report athlete-exposure and injury data. Athlete-exposure (A-E) was defined as 1 athlete’s participation in a practice or competition. Injury was defined as (1) occurring during an organized high school practice or competition, (2) requiring medical attention by a team AT or a physician, and (3) resulting in restriction of the student-athlete’s participation in either practice or competition for 1 or more days. Additionally, for each injury, the AT completed an injury report form that collected data on athlete demographics, where and when the injury occurred, concussion symptoms resolution time, length of time until return to play, injury recurrence, etc. Athletic trainers were able to view, edit, and update previously entered information throughout the study period.

Data from High School RIO were analyzed to assess the rates and patterns of sport-related concussion. The overall rate of injury was calculated as the ratio of injuries per 1000 total A-Es. Injury rates were also calculated as the ratio of practice injuries per 1000 practice exposures and as the ratio of competition injuries per 1000 competition exposures. To calculate national estimates of the number of high school injuries, each reported injury was assigned a sample weight based on the inverse of the probability of the school’s selection into the study (based on the total number of US high schools in each of the 8 sampling strata).\textsuperscript{18} If a school dropped out of the surveillance study, a replacement school from the same sampling stratum was enrolled. Data were analyzed using SPSS software (version 14.0; SPSS Inc, Chicago, IL) and Epi Info (version 6.0; Centers for Disease Control and Prevention, Atlanta, GA). Statistical analyses included calculation of rate ratios (RRs), proportion ratios (PRs), and χ\textsuperscript{2} tests. All 95% confidence intervals (CIs) not containing 1.0 with \(P\) values of less than .05 were considered statistically significant. As an example, PRs were calculated as follows:

\[
PR = \frac{\text{national estimated # girls’ soccer’ concussions/ total girls’ soccer injuries}}{\text{national estimated # boys’ soccer concussions/ total boys’ soccer injuries}}
\]

The NCAA has maintained the ISS for intercollegiate athletics since 1982. The primary goal of the NCAA ISS is to collect injury and exposure data from a representative sample of NCAA institutions in a variety of sports. Relevant data are then shared with NCAA sport and policy committees for making evidence-based decisions on health and safety issues.\textsuperscript{10} In 2004, the NCAA converted from a paper-based data collection system to the current Web-based platform. Participation in the NCAA ISS is voluntary and available to all member institutions. The goal of the NCAA ISS is to obtain participation from at least 10% of all schools sponsoring a particular sport, with appropriate representation of Divisions I, II, and III. In 2005–2006, 180 schools participated in ISS data collection for up to 16 sports through their ATs. Each participating school entered data for the sports of its choosing; thus each sport had a different sample size. This sampling scheme attempted to balance the needs of maintaining a representative cross-section of institutions while accommodating the needs of the voluntary participants. The NCAA ISS does not calculate national estimates.

High School RIO was closely modeled after the NCAA ISS. The 2005–2006 data used for analysis in this study represented the first year of High School RIO data collection at the high school level and the second year of Web-based NCAA ISS data collection at the collegiate level. Because High School RIO used the same definitions of injury and exposure as those in the NCAA ISS, the injury rates among high school and collegiate athletes were directly compared. Nationwide Children’s Hospital Institutional Review Board approved this study.

RESULTS

Incidence and Rates

In the 9 high school sports studied over the course of the 2005–2006 school year, 4431 injuries were reported, 396 (8.9%) of which were concussions. This included 137 concussions (34.6%) that occurred in practice and 259 (65.4%) that occurred during competition. These injuries were sustained during the course of 1 730 764 athletic exposures (1 246 499 practice and 484 265 competition exposures), resulting in a concussion injury rate of 0.23 concussions per 1000 A-Es (practice rate = 0.11 concussions per 1000 A-Es, competition rate = 0.53 concussions per 1000 A-Es). The weighted national estimate for the number of concussions sustained in all sports was 135 901. Based on the national estimate, the majority of concussions resulted from participation in football (40.5%, n = 55 007), followed by girls’ soccer (21.5%, n = 29 167), boys’ soccer (15.4%, n = 20 929), and girls’ basketball (9.5%, n = 12 923). The rate of concussion was higher in competition than in practice for all sports except high school girls’ softball and volleyball (Table 1). Because only 6 concussions were reported in volleyball, this sport will not be discussed in detail below.
Symptoms and Return to Play

Among high school athletes, the most commonly reported concussion symptom was headache (40.1%, \( n = 54,494 \)), followed by dizziness (15.3%, \( n = 20,743 \)), and confusion (8.6%, \( n = 11,752 \)). Other symptoms included loss of consciousness (3.9%, \( n = 5,302 \)) and amnesia (6.4%, \( n = 8,679 \)). Overall, 16.8% (\( n = 22,873 \)) of high school athletes suffering a concussion had previously suffered a sport-related concussion, either that season or in a previous season; more than 20% of concussions in boys’ and girls’ soccer and basketball were recurrent concussions. In more than 50% of athletes in sports other than girls’ basketball and softball, concussion symptoms resolved in 3 days or less (Figure 1). More than 50% of athletes in every sport returned to play in 9 days or less (Figure 2).

Risk Factors in High School Athletes by Sport

Football. The highest proportion of concussion injuries occurred during running plays (Table 2) and resulted from contact with another person (Figure 3). More specifically, tackling occurred during running plays (Table 2) and resulted from contact with another person (Figure 3). More than 50% of athletes in every sport returned to play in 9 days or less (Figure 2).

High School Soccer. Girls had a higher rate of concussion (0.36 concussions per 1000 A-Es) than boys (0.22 concussions per 1000 A-Es) (RR = 1.68, 95% CI = 1.08, 2.60, \( P = .03 \)) (Table 1), and concussions represented a greater proportion of injuries among girls (15.1%, \( n = 29,167 \)) than boys (9.4%, \( n = 20,929 \)) (PR = 1.61, 95% CI = 1.59, 1.64, \( P < .01 \)). The risk factors for concussion in soccer differed significantly by sex. Among both boys’ and girls’ soccer players, the activity most frequently associated with concussions was heading the ball (40.5%, \( n = 8433 \), and 36.7%, \( n = 10,714 \), respectively) (Table 2). Additionally, 64.1% (19,147) of injuries sustained while heading the ball were concussions. Contact with another person resulted in a greater proportion of concussions in boys (85.3%, \( n = 17,857 \)) than in girls (58.3%, \( n = 17,008 \)) (PR = 1.46, 95% CI = 1.45, 1.48, \( P < .01 \)) (Figure 3). However, contact with the ground (22.6%, \( n = 6588 \), and 6.0%, \( n = 1253 \), respectively) (PR = 3.77, 95% CI = 3.56, 4.00, \( P < .01 \)) and contact with the soccer ball (18.3%, \( n = 5,350 \), and 8.2%, \( n = 1716 \), respectively) (PR = 3.68, 95% CI = 3.45, 3.92, \( P < .01 \)) were related to a significantly greater proportion of concussions in girls than in boys. Another risk factor associated with concussions was goaltending, with 21.7% (\( n = 8116 \)) of injuries to goalkeepers being concussions, compared with 11.1% (\( n = 41,878 \)) of injuries to other positions (PR = 1.96, 95% CI = 1.92, 2.00, \( P < .01 \)).

High School Basketball. Girls had a higher rate of concussion (0.21 concussions per 1000 A-Es) than boys (0.07 concussions per 1000 A-Es) (RR = 2.93, 95% CI = 1.64, 5.24, \( P < .01 \)) (Table 1), and concussions represented a greater...
Figure 1. National estimates of concussion symptom resolution time for high school athletes, High School Sports-Related Injury Surveillance Study, United States, 2005–2006 school year.

Figure 2. National estimates of length of time until return to play after concussion for high school athletes, High School Sports-Related Injury Surveillance Study, United States, 2005–2006 school year.

<table>
<thead>
<tr>
<th>Sport*</th>
<th>Activity</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Football</td>
<td>Blocking drill</td>
<td>(n = 55,007)** 2225 4.1%</td>
</tr>
<tr>
<td></td>
<td>General play</td>
<td>1866 3.4%</td>
</tr>
<tr>
<td></td>
<td>Kick-off coverage/return</td>
<td>3238 5.9%</td>
</tr>
<tr>
<td></td>
<td>Passing play (offense/defense)</td>
<td>8928 16.3%</td>
</tr>
<tr>
<td></td>
<td>Punt coverage/return</td>
<td>1497 2.7%</td>
</tr>
<tr>
<td></td>
<td>Running play (offense/defense)</td>
<td>30,418 55.4%</td>
</tr>
<tr>
<td></td>
<td>Tackling drill</td>
<td>2833 5.2%</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>3895 7.1%</td>
</tr>
<tr>
<td>Wrestling</td>
<td>Conditioning</td>
<td>(n = 5935) 608 10.2%</td>
</tr>
<tr>
<td></td>
<td>Escape</td>
<td>377 6.4%</td>
</tr>
<tr>
<td></td>
<td>Fall</td>
<td>200 3.4%</td>
</tr>
<tr>
<td></td>
<td>Riding</td>
<td>153 2.6%</td>
</tr>
<tr>
<td></td>
<td>Sparring</td>
<td>1297 21.9%</td>
</tr>
<tr>
<td></td>
<td>Takedown</td>
<td>2526 42.6%</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>774 13.0%</td>
</tr>
<tr>
<td>Soccer</td>
<td>Boys (n = 20,929)** Attempting a slide tackle</td>
<td>959 4.6%</td>
</tr>
<tr>
<td></td>
<td>Ball handling/dribbling</td>
<td>0 0</td>
</tr>
<tr>
<td></td>
<td>Blocking shot</td>
<td>673 3.2%</td>
</tr>
<tr>
<td></td>
<td>Chasing loose ball</td>
<td>286 1.4%</td>
</tr>
<tr>
<td></td>
<td>Defending</td>
<td>780 3.7%</td>
</tr>
<tr>
<td></td>
<td>General play/other</td>
<td>2203 10.6%</td>
</tr>
<tr>
<td></td>
<td>Goaltending</td>
<td>4268 20.5%</td>
</tr>
<tr>
<td></td>
<td>Heading ball</td>
<td>8433 40.5%</td>
</tr>
<tr>
<td></td>
<td>Receiving a slide tackle</td>
<td>0 0</td>
</tr>
<tr>
<td></td>
<td>Receiving pass</td>
<td>2180 10.5%</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>1045 5.0%</td>
</tr>
<tr>
<td></td>
<td>Girls (n = 29,167)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Boys (n = 20,929)**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Girls (n = 29,167)</td>
<td></td>
</tr>
<tr>
<td>Basketball</td>
<td>Boys (n = 38,23) Ball handling/dribbling</td>
<td>399 10.4% 2456 19.0%</td>
</tr>
<tr>
<td></td>
<td>Chasing loose ball</td>
<td>994 26.0% 1367 10.6%</td>
</tr>
<tr>
<td></td>
<td>Defending</td>
<td>513 13.4% 2872 22.2%</td>
</tr>
<tr>
<td></td>
<td>General play/other</td>
<td>0 226 1.8%</td>
</tr>
<tr>
<td></td>
<td>Passing</td>
<td>0 257 2.0%</td>
</tr>
<tr>
<td></td>
<td>Rebounding</td>
<td>1164 30.5% 2151 16.8%</td>
</tr>
<tr>
<td></td>
<td>Receiving pass</td>
<td>259 6.8% 147 1.1%</td>
</tr>
<tr>
<td></td>
<td>Shooting</td>
<td>494 12.9% 2069 16.0%</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>0 688 5.3%</td>
</tr>
<tr>
<td></td>
<td>Girls (n = 12,923)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Boys (n = 38,23)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Girls (n = 12,923)</td>
<td></td>
</tr>
<tr>
<td>Baseball and softball</td>
<td>Baseball (n = 1991) Batting</td>
<td>1008 50.6% 246 6.9%</td>
</tr>
<tr>
<td></td>
<td>Catching</td>
<td>171 8.6% 1057 29.7%</td>
</tr>
<tr>
<td></td>
<td>Fielding</td>
<td>100 5.0% 398 11.2%</td>
</tr>
<tr>
<td></td>
<td>General play</td>
<td>171 8.6% 104 2.9%</td>
</tr>
<tr>
<td></td>
<td>Pitching</td>
<td>100 5.0% 246 6.9%</td>
</tr>
<tr>
<td></td>
<td>Running bases</td>
<td>0 152 4.3%</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>441 22.1% 1355 38.1%</td>
</tr>
<tr>
<td></td>
<td>Softball (n = 35,58)</td>
<td></td>
</tr>
</tbody>
</table>

*Due to the small sample size of concussions suffered by volleyball players, volleyball was excluded from analyses of activity involving nationally weighted data.

**Excludes injuries in which activity associated with concussion was not reported.

portion of total injuries among girls (11.7%, n = 12,923) (PR = 3.09, 95% CI = 2.98, 3.20, P < .01) than boys (3.8%, n = 3823). Boys had a quicker symptom resolution and return to play than girls (Figures 1 and 2). This was particularly true for student-athletes returning after 1 to 2 days postconcussion (PR = 38.21, 95% CI = 30.44, 47.96, P < .01).

Among girls, a greater proportion of concussions than all other injuries were sustained while defending (16.8%, n = 2872) compared with other plays (10.8%, n = 10,051) (PR = 1.56, 95% CI = 1.50, 1.62, P < .01). With regard to specific activities within basketball, girls sustained a greater proportion of concussions while ball handling/dribbling (19.0%, n = 2456) (PR = 1.83, 95% CI = 1.65, 2.02, P = .01) and while defending (22.2%, n = 2872) (PR = 1.66, 95% CI = 1.52, 1.81, P < .01) than boys (10.4%, n = 399, and 13.4%, n = 513, respectively) (Table 2). Conversely, boys sustained a greater proportion of concussions while chasing loose balls (26.0%, n = 994) (PR = 2.46, 95% CI = 2.28, 2.64, P < .01) and rebounding (30.5%, n = 1164) (PR = 1.83, 95% CI = 1.72, 1.95, P < .01) than girls (10.6%, n = 1367, and
16.6%, n = 2151, respectively) (Table 2). A larger proportion of boys (34.0%, n = 1299) than girls (22.0%, n = 2850) received a concussion due to contact with the playing surface (PR = 1.54, 95% CI = 1.46, 1.63, P < .01) (Figure 3). A small proportion of girls (6.0%, n = 769) and no boys reported a concussion resulting from contact with the ball.

High School Wrestling. In wrestling, takedowns were responsible for 42.6% (n = 2526) of the concussions (Table 2) and were more likely to lead to a concussion (7.6%, n = 769) and no boys reported a concussion resulting from contact with the ball. Therefore, a larger proportion of concussions among baseball players (6.0%, n = 1299) than softball players (6.9%, n = 2202) could be attributed to being hit by a pitch (PR = 1.81, 95% CI = 1.78, 1.80, P < .01) than softball players (59.1%, n = 2102) (Figure 3). Furthermore, a larger proportion of concussions among baseball players (50.6%, n = 1008) could be attributed to being hit by a pitch (PR = 1.69, 95% CI = 1.61, 1.78, P < .01) than softball players (68.8%, n = 2449) than baseball players (64.2%, n = 1279) (PR = 1.07, 95% CI = 1.03, 1.11, P < .01) (Figure 1). However, a greater proportion of baseball players returned to play within 6 days (52.9%, n = 1053) than softball players (15.5%, n = 550) (PR = 4.2, 95% CI = 3.13, 3.73, P < .01) (Figure 2).

Comparison of High School and Collegiate Athletes. In the 2005–2006 school year, for the 9 college sports corresponding to those studied in High School RIO, a total of 8293 injuries were reported, including 482 (5.8%) concussions. In general, the overall rate of concussion was higher in the collegiate sports than their high school counterparts, although the difference was not significant in baseball (Table 1). With the exception of high school baseball and softball players, collegiate concussion rates were higher than high school rates in both competition and practice. Conversely, concussions comprised a greater proportion of total injuries sustained by high school athletes than by collegiate athletes in all sports except volleyball and men’s basketball (Figure 4).

DISCUSSION

As participation in high school sports continues to increase, ATs will continue to be heavily relied upon to diagnose and treat concussions. Sport-related injury surveillance systems can provide the scientific data needed to calculate injury rates, monitor patterns of injury, and identify risk factors. For example, our data demonstrated differences in sport-related concussion among sports and between the sexes and levels of play (ie, high school versus collegiate). By identifying patterns that could predict concussions, we may be able to reduce concussion rates through targeted, evidence-based interventions.

In our study, concussions represented 8.9% of all high school sport-related injuries. This amount is higher than the 5.5% reported by authors of a study of high school athletes conducted a decade ago using similar definitions of injury and exposure and the 7.5% reported in authors of a more recent North Carolina study who included all concussions regardless of time loss. One potential explanation is that the prior re-
search included sports not included in our study, such as girls’
field hockey12 and track and field,9 which have relatively low
concussion rates. However, the higher concussion rate reported
here may reflect an increased awareness of, and subsequent
diagnosis and treatment of, concussions.22 Educational cam-
paigns, such as the distribution of the “Heads Up: Concussion
in High School Sports” tool kit by the Centers for Disease
Control and Prevention, National Center for Injury Prevention
and Control,23 have increased awareness of concussion symp-
toms among coaches, athletes, and parents. In general, contact
with another person appears to be the risk factor responsible
for most of the concussions among high school athletes (Fig-
ure 3). Full-contact sports (eg, football and wrestling) as well
as partial-contact sports (eg, soccer and basketball) had the
highest competition-related rates of concussion.

In sports both sexes played in, high school girls had higher
rates of concussion than boys. This trend, which was also seen
among college athletes (Table 1), has been noted previously.11,12
In our study, sex differences in risk factors for con-
cussion were also noted. In soccer, contact with the ground or
with the ball was a more frequent cause of concussion in girls
than boys (Table 2). Comparing baseball and softball, boys
were more likely than girls to sustain a concussion after being
hit by a pitch, a finding possibly attributable to the different
pitching styles and balls. In soccer, more boys suffered con-
cussions goaltending, whereas more girls sustained concus-
sions defending. In basketball, more boys sustained concus-
sions while rebounding and chasing loose balls, whereas more
girls sustained concussions defending and ball handling. Such
differences may be attributable to differences in the style of
play.

One possible explanation for the observed sex differences
in concussion rates is biomechanical differences. Barnes et al24
suggested that differences in concussion symptoms between
male and female soccer players may be due to smaller head
to ball ratios or weaker necks. Queen et al25 demonstrated that
in children, an increased head mass resulted in decreased linear
acceleration of the head. In a study of collegiate soccer play-
ers,26 females had 26% less total mass in their head and neck
than males. In another recent study,27 females demonstrated
greater angular acceleration and displacement of the head and
neck. This movement was despite the earlier activity of the
sternocleidomastoid muscle in females, which should have act-
ed to stabilize and decrease acceleration and movement of the
head.27 Although this acceleration may not play as great a role
in soccer players, who learn to resist such forces with the head
in practice and competition,26 tests using accelerative forces
large enough to observe sex differences in soccer players have
not yet been performed.26 Nevertheless, head and neck accel-
eration differences between the sexes may play a role in other
sports.

Cultural explanations may also play a role in the observed
sex differences in concussion rates. Traditionally, US society
has tended to be more protective of female athletes.28 This
may lead coaches, ATs, and parents to treat head injuries in
female athletes more seriously or to delay their return to play.
Similar cultural tendencies may encourage male athletes to
play despite injuries or to avoid reporting injuries, particularly
in certain sports. Thus, some boys suffering from head injuries
may not report their symptoms for fear of being removed from
play.29 A reluctance to report injury was demonstrated in high
school football players30: only 47.3% of players claiming to
have suffered a concussion reported their injury. Underesti-
mating the seriousness of the injury, not wanting to be with-

Figure 4. Concussions as a percentage of total injuries sustained by high school and collegiate athletes, High School Sports-Related
drawn from competition, and not being aware of having suffered a concussion have been cited as reasons for underreporting concussion injury.30

We found that although rates of concussion were higher among collegiate athletes, concussions represented a higher proportion of all injuries sustained by high school athletes. This finding is contrary to the work of several authors,16,17 who reported that rates of concussions were higher among high school athletes than collegiate athletes. The potential for more playing time, lower-quality protective equipment, and lower skill level were suggested as reasons why a higher rate of concussion might be expected among high school athletes.16 Conversely, collegiate athletes play at a faster, more competitive level and are bigger and stronger than high school athletes,11 which some argue may increase the former’s risk of concussion. The truth likely lies somewhere in between, and it may be that a lower level of skill leads to a higher proportion of concussions compared with other injuries at the high school level. Furthermore, greater intensity of play at the collegiate level may predispose those athletes to a higher rate of concussion, as well as increase the rate of other injuries and lower the proportion of all injuries that are concussions. Recently, however, only small differences were noted between head impact in high school and collegiate football players.31 Thus, the higher rates of concussion at the collegiate level may stem from the intensity of play leading to a greater number of impacts rather than greater force of impact.

This study, like all studies, had limitations. Eligibility was limited to high schools with NATA-affiliated ATs. Thus, although schools were selected to be nationally representative with respect to geographic location and school size, our findings may not be generalizable to schools without an AT. However, the increased quality of data provided by these medically trained reporters justified this inclusion criterion. Another potential limitation was our definition of injury. Only time-loss injuries that came to the attention of the school’s AT were included in the study. In addition, low-grade concussions that were not accurately diagnosed and concussions that did not keep the athlete out of play for at least 1 day were not captured. Therefore, concussion rates among high school athletes are likely actually higher than those reported here. Another potential limitation was the definition of an A-E as 1 athlete’s participation in a practice or competition, rather than the more precise approach based on the minutes an athlete was exposed.32 This definition was necessitated by our use of ATs as reporters because it was not possible for high school ATs to be simultaneously present at all athletic practices and competitions to collect such detailed exposure data. Additionally, our definitions of injury and A-E mirrored the definitions used in the NCAA ISS, which enabled us to directly compare concussion rates among high school and collegiate athletes. Finally, although we used a weighting factor to estimate national numbers of high school concussion injuries, we were unable to apply weighting factors to the standard error when calculating confidence intervals and P values because the NCAA ISS values were not based on national averages.

The rates of concussion among high school and collegiate athletes shown in this study are higher than those previously reported.8,11,12 Competition-related concussion rates were highest among full-contact sports (football and wrestling) and partial-contact sports in which player-to-player contact often occurs (ie, soccer and basketball). We found the rates of concussions among high school athletes were lower than those among collegiate athletes, whereas concussions comprised a greater proportion of total injuries among high school athletes. Additionally, for sports both sexes played, the rate of concussion as well as the proportion of all injuries attributable to concussions was higher among females. With an estimated 135 901 concussions occurring nationally among high school athletes participating in these 9 sports during the 2005–2006 academic year, we must attempt to identify methods for preventing these serious sports injuries.

Although the risk of sport-related concussion does not outweigh the many benefits of sport participation, preventive interventions should be implemented to decrease concussion rates to the lowest possible levels. Development of effective sport-related concussion preventive measures depends upon increasing our knowledge of concussion rates, patterns, and risk factors. Future studies are needed to further investigate potential interventions such as educational programs,23 improved protective equipment, increased conditioning, enhanced enforcement of sporting rules, and policy changes33 that might prevent concussions at both the high school and collegiate levels. For example, while enhanced officiating and rule changes may reduce sex differences in concussion rates by addressing differences in style of play, improved protective gear may need to account for biomechanical differences. Additionally, improved concussion management driven by a better understanding of concussion symptoms and symptom resolution time may reduce the long-term sequelae of concussions. We support current guidelines regarding concussion diagnosis, treatment, and athletes’ return to play, but additional research is necessary to determine the validity of self-reported symptoms29 and symptom resolution as viable determinants of return to play. Furthermore, because no consensus as to the effects of multiple concussions exists,3–5 we believe caution should be exercised when clearing athletes with multiple concussions to return to play. Such caution may be especially pertinent to high school athletes who suffered concussions and then continue to play in college.

ACKNOWLEDGMENTS

We acknowledge Rosemary Schmalz, PhD, from the National Collegiate Athletic Association (NCAA) Injury Surveillance System, for aiding in the analysis of collegiate concussions. The lead author was funded by the Samuel J. Roessler Scholarship from the Landcare Honor Society at The Ohio State University. This research was funded by the Centers for Disease Control and Prevention (CDC) grant #R49/CEOO0674-01. The content of this report is solely the responsibility of the authors and does not necessarily represent the official view of the CDC or the NCAA.

REFERENCES


