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## Epidemiology of Meniscal Injuries in U.S. High School Athletes from 2007/08 – 2012/13

Joshua Mitchell, William Graham, Thomas M. Best, Christy Collins, Dustin W. Currie, R. Dawn Comstock, and David C. Flanigan

Research conducted at The Ohio State University Wexner Medical Center, Columbus, OH, and Colorado School of Public Health, Aurora, CO

### Abstract

**Purpose**—Knowledge of epidemiologic trends of meniscal injuries in young active populations is limited. Better awareness of injury patterns is a first step to lowering injury rates. Our hypothesis was that meniscal injuries in high school athletes would vary by gender, sport, and type of exposure.

**Methods**—During 2007–2013, a large nationally disperse sample of US high schools reported athlete exposure and injury data for 22 sports by having certified athletic trainers complete an internet-based data collection tool.

**Results**—1,082 meniscal injuries were reported during 21,088,365 athlete-exposures for an overall injury rate of 5.1 per 100,000 athlete exposures. The overall rate of injury was higher in competition (11.9) than practice (2.7) (RR = 4.4; 95% CI, 3.9–5.0), and 12/19 sports showed significantly higher injury rates in competition compared to practice. Of all injuries, 68.0% occurred in boys, yet among the gender-comparable sports of soccer, basketball, track and field, lacrosse, and baseball/softball injury rates were higher for girls than boys (5.5 and 2.5, respectively, RR = 2.2; 95% CI, 1.8–2.7). Contact injury represented the most common mechanism (55.9%). Surgery was performed for the majority of injuries (63.8%), and 54.0% of athletes had associated intra-articular knee pathology.

**Conclusions**—Meniscal injury patterns among high school athletes vary by gender, sport, and type of exposure. Overall rates are higher for boys, but this is driven by football; however in gender-comparable sports girls may be at higher risk for meniscal injury. Our study is clinically relevant because recognition of distinct differences in these injury patterns will help drive evidence-based, targeted injury prevention strategies and efforts.

**Level of Evidence**—Level III

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CORRESPONDING AUTHOR: David C. Flanigan, M.D. The Ohio State University Sports Medicine Center and Cartilage Restoration Program, 2050 Kenny Road, Suite 3100, Columbus, OH 43221. Phone: 614-293-3600; Fax: 614-293-4399. david.flanigan@osumc.edu.

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## Keywords

meniscus; mechanism of injury; high-school athletes; gender

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## Introduction

Steady increases in high school athletics participation over the past decade resulted in 7.6 million participants during the 2011–12 academic year [20]. While many health benefits are associated with participation in sports, interscholastic athletics incurs risk of acute injuries which can have long-term consequences [8]. Meniscal injuries are one such injury, with a reported mean annual incidence rate in the general population of 66–70 per 100,000 people [11, 12, 21]. Concurrently, arthroscopic treatment for meniscal injuries is an extremely common orthopaedic procedure in the United States [2, 16, 27]. Recognition of risk factors for the development of meniscal injuries in youth athletes is essential to preserving the long-term health of the knee as meniscal lesions are associated with a 4 to 14 times increase in the risk of knee osteoarthritis [9, 17, 18, 28, 32, 33].

Published epidemiologic studies regarding meniscal pathology leave many questions unanswered, though broad trends have been established. The two most common etiologies are acute trauma and degenerative processes [5, 11, 18]. The mean age of traumatic meniscal injury is 30 years and the mean age for degenerative meniscal lesions is 40 years [18]. The peak incidence of meniscal injuries in males is between 21–30 years and in females between 11–20 years [6, 23]. The incidence of meniscal injury for both genders declines with increasing age [6, 23].

Beyond establishing broad trends, published epidemiologic data on meniscal injuries remains limited. Most studies fail to assess mechanism of injury [5, 23]. There are limited data on specific populations. Some researchers have targeted elite athletic subgroups such as professional basketball players [35] and collegiate soccer players [3] or military populations [15, 31]. Several studies include limited data on meniscal injuries as part of a larger focus on knee injuries [7, 10, 13, 19, 21, 29] or overall sports injuries [14]. However, data on meniscal injuries specifically in children are outdated or lack generalizability [1]. Although some publications report meniscal injury incidence by sport [4, 14, 19, 34] they lack athletic exposure information and thus cannot be used to compare rates by sport or gender.

The objective of this study was to establish the epidemiology of meniscal injuries among U.S. high school athletes in 22 sports; to compare injury rates by sport, gender, and type of athletic exposure; and to delineate injury pattern by mechanism and severity. Defining more comprehensive epidemiological trends regarding meniscal injuries among U.S. high school athletes will lay groundwork for future evidence-based prevention and treatment strategies.

## Materials and Methods

Data were evaluated from the National High School Sports-Related Injury Surveillance System, High School Reporting Information Online (RIO), an Internet-based sports injury surveillance system sampling a large national convenience sample, which has been described

previously [25]. Beginning in 2005/06, high schools with a National Athletic Trainers' Association-affiliated certified athletic trainer (AT) were invited to participate. Willing participants were categorized into 8 strata based on school population (enrollment 1000 or >1000) and geographic location. From these strata, 100 schools were randomly selected to participate in the nationally representative sample to report data from nine sports. High School RIO has since expanded to include 13 additional sports (Table 1). An insufficient number of schools from each strata volunteered to report for each additional sport to enable random selection, therefore data for these sports were collected from a large national convenience sample. At the end of each study year an internal validity check is conducted among a random 5% sample of reporting high schools. Although the results vary slightly each year, the sensitivity, specificity, positive predictive value, and negative predictive value have each been well over 90% for each internal validity check. This is a strong indication of the accuracy of the data collected by High School RIO.

ATs from participating high schools reported injury incidence and athlete exposure weekly for their assigned sports. Beginning with the 2007/08 academic year, ATs were asked to specify structures injured when reporting knee injuries, including the meniscus. Therefore this study utilizes data on all 22 sports included in High School RIO from 2007/08–2012/13. An athlete exposure was defined as one athlete participating in one athletic practice or competition. Reportable injuries (1) occurred during organized practice or competition, (2) required medical attention by an AT or a physician, and (3) resulted in restriction of participation for 1 day or (4) resulted in fracture, concussion, or dental injury regardless of whether there was subsequent restriction in participation. For each injury, the AT completed a detailed report on the athlete (age, height, weight, etc), the injury (site, diagnosis, severity, etc), and the injury event (activity, mechanism, etc). Reporters were able to update previously submitted reports as needed. The study was approved by the Institutional Review Board of Nationwide Children's Hospital, Columbus, OH, protocol IRB08-00003.

### Statistical analysis

Data were analyzed using SPSS software, version 21.0 (SPSS Inc, Chicago, Illinois, USA). Rates and proportions were calculated using unweighted case counts. Rate ratios (RRs) and injury proportion ratios (IPRs) were used to measure magnitudes of associations. RRs and IPRs whose 95% confidence intervals did not contain 1.00 were considered statistically significant.

### Results

A total of 1,082 meniscal injuries were reported over the course of 6 school years. There were three sports in which no meniscal injuries were reported: boys' volleyball, boys' swimming and diving, and boys' cross country, thus the athlete exposures from these sports were excluded from analysis. The 1,082 meniscal injuries occurred during 21,088,365 athlete exposures for an overall injury rate of 5.1 per 100,000 athlete exposures (Table 2). Boys' football alone accounted for 42.4% of all injuries. The sports with the highest injury rates were boys' football, girls' soccer, girls' basketball, and boys' wrestling (Table 3).

The overall injury rate per 100,000 athlete exposures was higher for boys than girls (5.9 and 4.4, respectively, RR = 1.4; 95% CI, 1.2–1.5), with 68% of all reported injuries occurring in boys. This overall gender difference was largely driven by the high injury rate in football (11.2), however this trend reversed in gender-comparable sports. In soccer, basketball, track and field, lacrosse, and baseball/softball the overall injury rate per 100,000 athlete exposures was higher for girls than boys (5.5 and 2.5, respectively, RR =2.2; 95% CI, 1.8, 2.7).

The overall injury rate per 100,000 athlete exposures was higher in competition (11.9) than practice (2.7) (RR = 4.4; 95% CI, 3.9–5.0). The highest competition injury rate occurred in boys' football (40.7 per 100,000 athlete exposures) followed by girls' soccer (23.2). Meniscal injuries accounted for 15.1% of all knee injuries (Figure 1).

Overall non-contact injury mechanism accounted for 38.2% of meniscal injuries and player-player contact accounted for 41.9% (Table 2). Overall, boys had a higher proportion of injuries caused by player-player contact than girls (IPR = 1.7; 95% CI, 1.4–2.1), while girls had a higher proportion of injuries caused by a non-contact mechanisms (IPR=1.4; 95% CI, 1.2–1.6).

Rotation around a planted foot/inversion was the most common specific action causing injury overall. For soccer athletes, this accounted for the largest proportion at 41.2% in boys and 34.8% for girls. Likewise, for boys' baseball and girls' softball, the most common mechanism of injury was rotation around a planted foot/inversion (25.0% and 36.4%, respectively). However, for both boys' and girls' basketball the most common specific activity causing injury was jumping/landing (33.9% and 42.3%, respectively). For boys' football, 23.0% of the injuries occurred while the athlete was being tackled, followed by rotation around a planted foot/inversion with 21.0%. In girls' volleyball jumping/landing accounted for 37.0% of injuries, followed by rotation around a planted foot/inversion (25.9%). The majority of meniscal injuries reported for boys' wrestling occurred during takedown (42.4%) followed by sparring (23.2%) and escape (8.1%).

Following meniscal injury, medical disqualification was the most common outcome (29.0%), with an additional 18.0% returning to play in 1–3 weeks. The majority of meniscal injuries required surgical intervention (63.8%) (Figure 2). Among the gender-comparable sports there were no significant differences in the proportion of injuries resulting in surgery. Concomitant injuries were reported in 54.0% of knees with meniscal injuries. The most common additional structures injured included the anterior cruciate ligament [ACL] (36.9%) and the medial collateral ligament [MCL] (24.2%)

Analyzing need for surgery based on playing surface revealed no significant differences.

## Discussion

The most important finding of the present study was a significantly higher meniscal injury rate for females than males. The highest meniscal injury rates occurred in boys' football, girls' soccer, girls' basketball and boys' wrestling. These findings are consistent with previous reports identifying sports requiring extensive pivoting and lateral movement as high risk for meniscal injury [3, 4, 5, 14, 19].

Previous studies have reported that between 71% and 79% of sport-related meniscal injuries occur in male athletes [19, 30, 34]. Consistent with those reports this study found that males accounted for 68.0% of all meniscal injuries, and overall injury rates were significantly higher for males than females. However, when analyzing only gender-comparable sports, the injury rate was significantly higher for females than males. Baker et al [4] previously reported that females were at higher risk for meniscal injury than males when participating in the sport of alpine skiing. The present study significantly expands upon those findings, demonstrating that for females participating in high school soccer, basketball, softball, lacrosse, and track and field the risk of meniscal injury is more than double that of their male counterparts. This may have important implications in the development of future injury prevention strategies.

The present study also demonstrated the overall injury rate was significantly higher in competition than practice. The highest competition to practice injury rate ratios occurred in girls' soccer, boys' ice hockey, and boys' football, likely reflecting significant differences in intensity and speed of play between competition and practice. Conversely, the lowest competition to practice injury rate ratios occurred in cheerleading and girls' volleyball, suggesting the athletic actions and maneuvers required to practice cheerleading and volleyball are more similar to those performed in competition than in other sports.

Overall the most commonly reported injury mechanism injury was player-player contact, accounting for 41.9% of all injuries, followed by non-contact (38.2%). Consistent with previous reports, [11, 24] for most sports, the most common action causing injury was rotation around a planted foot. A study of NBA players reported 31.7% of meniscal injuries occurred via a non-contact mechanism [35]. When looking specifically at basketball the present study demonstrated a higher proportion of non-contact meniscal injuries for both males and females, 42.9% and 45.9%, respectively. This suggests younger basketball players, having not yet reached physical maturity, may be more susceptible to injury by rotation around a planted foot.

Meniscal injuries were found to account for 15.1% of all knee injuries in high school athletes, slightly higher than Majewski et al [19], who reported meniscal injuries constituted 14.4% of all knee injuries in athletes. While these findings are similar, that study analyzed a population that was not age restricted and utilized different clinical surveillance methods, limiting direct comparison.

Meniscal injuries often occur in conjunction with injury to other knee structures [11, 22, 26, 34]. In the present study 54.0% of reported meniscal injuries had at least one concomitant knee injury. The most common associated injury was ACL tear (36.9%), which is similar to previous reports observing 36.6% of meniscal tears having associated ACL tear [23].

The majority of meniscal injuries reported in the present study required surgical intervention (63.8%), though only 29.0% of injuries resulted in disqualification of the athlete for the remainder of the season or their career. There were no significant differences in need for surgery or time to return to play based on sport or gender. By not restricting data to isolated meniscal injuries, this study is limited in that return to play and need for surgery were likely

affected by concomitant knee pathology. Multiple knee injuries, particularly those involving the ACL or MCL, are more likely to require surgery and have longer recoveries prior to return to play and thus these injuries may have inflated our reported results on these measures.

Another limitation of this study is that some sports had fewer than 10 reported meniscal injuries. Small sample size limited the ability to analyze trends and determine significant differences in some sports. Continued injury surveillance is needed to better elucidate trends in those sports with low injury rates.

With millions of US high school students annually participating in interscholastic athletics the need for evidence-based injury prevention strategies is clear. The development of injury prevention models is predicated upon an understanding of injury patterns, injury rates, injury mechanisms, and sport specific risk. It has been well established that an intact meniscus is essential to the long-term health and function of the knee. Establishing detailed epidemiologic trends for meniscal injury in young athletes is an essential component of advocating for the long-term health of these young athletes knees.

## Conclusions

Meniscal injury patterns among high school athletes vary by gender, sport, and type of exposure. There are a few key clinically relevant findings of this study. The current study clearly defines American football as the greatest sport at risk for meniscus tears in high school athletics. However in gender-comparable sports girls may be at higher risk for meniscal injury. Most athletes with meniscus tears are able to return to sport in season, though often require surgery. Recognizing distinct differences in these injury patterns will help drive evidence-based, targeted injury prevention strategies and efforts.

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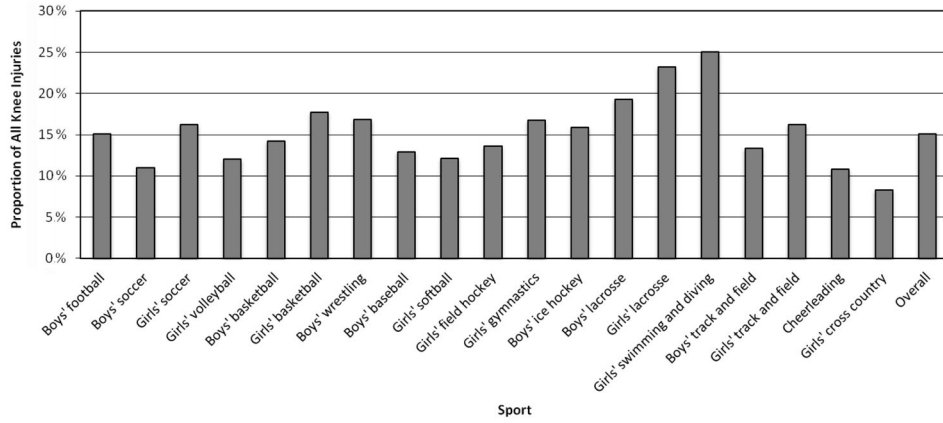
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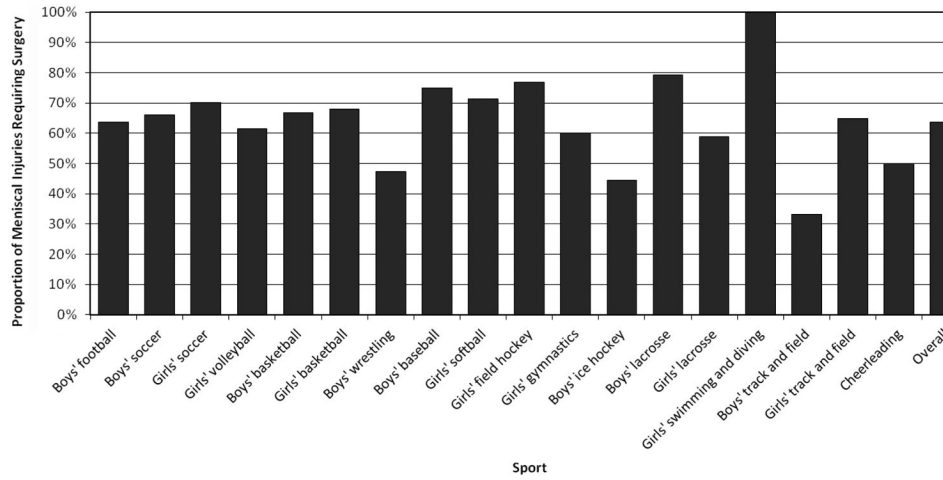
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**Figure 1.** Meniscal Injuries as a Proportion of All Knee Injuries, National High School Sports-Related Injury Surveillance Study, United States, 2007/08 – 2012/13.

\* Boys' swimming and diving, Boys' volleyball, and Girls' cheerleading reported no meniscal injuries during the study period and were therefore excluded from this analysis.



**Figure 2.** Proportion of Meniscal Injuries Requiring Surgery by Sport, National High School Sports-Related Injury Surveillance Study, United States, 2007/08 – 2012/13.  
 \* Boys' swimming and diving, Boys' volleyball, and Boys' cross country reported no meniscal injuries during the study period and where therefore excluded, as was Girls' cross country meniscal injury due to missing surgery data for the only meniscal injury.

**Table 1**

Sports Included in National High School Sports-Related Injury Surveillance Study, United States, 2007/08 – 2012/13.

6 Years of Data <sup>a</sup>	5 Years of Data	4 Years of Data	3 Years of Data	1 Year of Data
boy's football, boy's soccer, boy's basketball, boy's wrestling, boy's baseball, girl's soccer, girl's basketball, girl's volleyball, and girl's softball track and field	boys' ice hockey, boy's lacrosse, boy's swimming and diving, boy's track and field, girls' field hockey, girl's lacrosse, girls, swimming and diving, and girl's	girls' gymnastics, co-ed cheerleading	boy's volleyball	boys' cross country, and girls' cross country

<sup>a</sup>Playing apparatus included items like ball, base, goalpost, etc.

**Table 2**  
Meniscal Injury Rates per 100,000 Athlete-Exposures, National High School Sports-Related Injury Surveillance Study, United States, 2007/2008 – 2012/2013

Sport	Meniscal Injuries			Athlete-Exposures (AEs)			Rate per 100,000 AEs			Rate Ratio <sup>a</sup> (95% CI)
	Competition	Practice	Total	Competition	Practice	Total	Competition	Practice	Total	
Boys' football	279	180	459	685,169	3,416,209	4,101,378	40.7	5.3	11.2	<b>7.7</b> (6.4, 9.3)
Boys' soccer	38	15	53	467,046	1,095,909	1,562,955	8.1	1.4	3.4	<b>5.9</b> (3.3, 10.8)
Girls' soccer	92	25	117	396,368	906,157	1,302,525	23.2	2.8	9.0	<b>8.4</b> (5.4, 13.1)
Girls' volleyball	11	16	27	472,211	931,724	1,403,935	2.3	1.7	1.9	<b>1.4</b> (0.6, 2.9)
Boys' basketball	32	25	57	556,635	1,306,919	1,863,554	5.7	1.9	3.1	<b>3.0</b> (1.8, 5.1)
Girls' basketball	74	37	111	453,932	1,035,355	1,489,287	16.3	3.6	7.5	<b>4.6</b> (3.1, 6.8)
Boys' wrestling	48	53	101	365,742	1,025,088	1,390,830	13.1	5.2	7.3	<b>2.5</b> (1.7, 3.8)
Boys' baseball	9	7	16	486,145	907,092	1,393,237	1.9	0.8	1.1	<b>2.4</b> (0.9, 6.4)
Girls' softball	15	7	22	355,797	683,906	1,039,703	4.2	1.0	2.1	<b>4.1</b> (1.7, 10.1)
Girls' field hockey	8	7	15	150,923	327,580	478,503	5.3	2.1	3.1	<b>2.5</b> (0.9, 6.8)
Girls' gymnastics <sup>b</sup>	3	2	5	15,026	65,713	80,739	20.0	3.0	6.2	<b>6.6</b> (1.1, 39.3)
Boys' ice hockey	8	2	10	101,725	210,092	311,817	7.9	1.0	3.2	<b>8.3</b> (1.8, 38.9)
Boys' lacrosse	18	9	27	163,878	365,390	529,268	11.0	2.5	5.1	<b>4.5</b> (2.0, 9.9)
Girls' lacrosse	13	6	19	119,506	262,834	382,340	10.9	2.3	5.0	<b>4.8</b> (1.8, 12.5)
Girls' swimming and diving	2	2	4	96,302	406,775	503,077	2.1	0.5	0.8	<b>4.2</b> (0.6, 23.0)
Boys' track and field	5	8	13	245,343	1,042,517	1,287,860	2.0	0.8	1.0	<b>2.7</b> (0.9, 8.1)
Girls' track and field	8	13	21	200,439	850,747	1,051,186	4.0	1.5	2.0	<b>2.6</b> (1.1, 6.3)
Cheerleading <sup>c</sup>	1	3	4	210,306	592,865	803,171	0.5	0.5	0.5	<b>0.9</b> (0.1, 9.0)
Girls' cross country	0	1	1	19,519	93,481	113,000	0.0	1.1	0.9	-
<b>Gender-Comparable<sup>d</sup></b>										
<b>Boys'</b>	<b>102</b>	<b>64</b>	<b>166</b>	<b>1,919,047</b>	<b>4,717,827</b>	<b>6,636,874</b>	<b>5.3</b>	<b>1.4</b>	<b>2.5</b>	<b>3.9</b> (2.9, 5.4)
<b>Girls'</b>	<b>202</b>	<b>88</b>	<b>290</b>	<b>1,526,042</b>	<b>3,738,999</b>	<b>5,265,041</b>	<b>13.2</b>	<b>2.4</b>	<b>5.5</b>	<b>5.6</b> (4.4, 7.2)
<b>Total<sup>e</sup></b>	<b>664</b>	<b>418</b>	<b>1,082</b>	<b>5,562,012</b>	<b>15,526,353</b>	<b>21,088,365</b>	<b>11.9</b>	<b>2.7</b>	<b>5.1</b>	<b>4.4</b> (3.9, 5.0)
<b>Boys'</b>	<b>437</b>	<b>299</b>	<b>736</b>	<b>3,071,683</b>	<b>9,369,216</b>	<b>12,440,899</b>	<b>14.2</b>	<b>3.2</b>	<b>5.9</b>	<b>4.4</b> (3.8, 5.2)
<b>Girls'</b>	<b>226</b>	<b>116</b>	<b>342</b>	<b>2,280,023</b>	<b>5,564,272</b>	<b>7,844,295</b>	<b>9.9</b>	<b>2.1</b>	<b>4.4</b>	<b>4.8</b> (3.8, 5.9)

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<sup>g</sup>Practice is referent group; CI denotes Confidence Interval

<sup>h</sup>Caution should be used when interpreting results on tables and figures when considering sports with less than 10 total injuries such as gymnastics

<sup>c</sup>Cheerleading competition category also includes performance injuries and exposures

<sup>d</sup>Gender comparable sports included Soccer, Basketball, Lacrosse, Track and Field, and Baseball/Softball

<sup>e</sup>Cheerleading is included in the total rate but not the gender specific rates, as it is a co-ed sport

**Table 3**

Meniscal Injury Mechanism by Sport, National High School Sports-Related Injury Surveillance Study, United States, 2007/08 – 2012/13.

Sport	Player-player contact	Player-surface contact	Player-playing apparatus contact <sup>a</sup>	Contact (total)	No contact	Overuse/Chronic	Other	Total
Boys' football	56.8%	8.0%	0.4%	(65.2%)	31.7%	2.2%	0.9%	100.0%
Boys' soccer	38.5%	13.5%	7.7%	(59.7%)	34.6%	3.8%	1.9%	100.0%
Girls' soccer	47.9%	6.8%	4.3%	(59.0%)	37.6%	1.7%	1.7%	100.0%
Girls' volleyball	22.2%	25.9%	0.0%	(48.1%)	48.1%	3.7%	0.0%	100.0%
Boys' basketball	25.0%	19.6%	0.0%	(44.6%)	42.9%	10.7%	1.8%	100.0%
Girls' basketball	22.5%	19.8%	0.0%	(42.3%)	45.9%	7.2%	4.5%	100.0%
Boys' wrestling	44.9%	14.3%	1.0%	(60.2%)	33.7%	2.0%	4.1%	100.0%
Boys' baseball	12.5%	18.8%	18.8%	(50.1%)	43.8%	6.3%	0.0%	100.0%
Girls' softball	22.7%	13.6%	4.5%	(40.8%)	45.5%	9.1%	4.5%	100.0%
Girls' field hockey	6.7%	13.3%	0.0%	(20.0%)	73.3%	6.7%	0.0%	100.0%
Girls' gymnastics	0.0%	60.0%	0.0%	(60.0%)	40.0%	0.0%	0.0%	100.0%
Boys' ice hockey	40.0%	40.0%	10.0%	(90.0%)	10.0%	0.0%	0.0%	100.0%
Boys' lacrosse	38.5%	0.0%	0.0%	(38.5%)	53.8%	0.0%	7.7%	100.0%
Girls' lacrosse	5.9%	5.9%	0.0%	(11.8%)	76.5%	11.8%	0.0%	100.0%
Girls' swimming and diving	0.0%	25.0%	0.0%	(25.0%)	50.0%	0.0%	25.0%	100.0%
Boys' track and field	0.0%	7.7%	23.1%	(30.8%)	61.5%	7.7%	0.0%	100.0%
Girls' track and field	4.8%	23.8%	0.0%	(28.6%)	52.4%	19.0%	0.0%	100.0%
Cheerleading	25.0%	50.0%	0.0%	(75.0%)	0.0%	25.0%	0.0%	100.0%
Girls' cross country	0.0%	0.0%	0.0%	(0.0%)	100.0%	0.0%	0.0%	100.0%
Boys total	48.5%	10.5%	1.9%	(60.9%)	34.3%	3.0%	1.7%	100.0%
Girls total	27.9%	15.3%	1.8%	(45.0%)	46.5%	5.9%	2.6%	100.0%
<b>Total</b>	<b>41.9%</b>	<b>12.1%</b>	<b>1.9%</b>	<b>(55.9%)</b>	<b>38.2%</b>	<b>4.0%</b>	<b>2.0%</b>	<b>100.0%</b>

<sup>a</sup>Playing apparatus included items like ball, base, goalpost, etc.

\*Boys' swimming and diving, boys' volleyball and boys' cross country reported no meniscal injuries during the study period and were therefore excluded