The Effects of Level of Competition, Sport, and Sex on the Incidence of First-Time Noncontact Anterior Cruciate Ligament Injury

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Abstract:

Background: Anterior cruciate ligament (ACL) injuries are disabling and are associated with the early onset of posttraumatic osteoarthritis. Little is known regarding the incidence rate of first-time noncontact ACL injuries sustained during athletic events and how they are independently influenced by level of competition, type of sport, and the participant's sex.

Hypothesis: Level of competition (college or high school), type of sport (soccer, basketball, lacrosse, field hockey, football, rugby, volleyball), and the athlete's sex independently influence the incidence rate of first-time noncontact ACL injuries.

Study Design: Cohort study; Level of evidence, 2.

Methods: Between fall 2008 and spring 2012, first-time noncontact ACL injury data were collected from 8 colleges and 18 high schools across 7 sports. Athlete exposure was computed retrospectively using team rosters and numbers of scheduled practices and games. Injury incidence rates (IRs) were computed per 1000 athlete exposures. The independent effects of level of competition, sport, and sex on ACL injury risk were estimated by Poisson regression.

Results: Colleges reported 48 ACL injuries with 320,719 athlete exposures across all sports studied (IR = 0.150 per 1000 person-days), while high schools reported 53 injuries with 873,057 athlete exposures (IR = 0.061). After adjustment for differences in sport and sex, college athletes had a significantly higher injury risk than did high school athletes (adjusted relative risk [RR], 2.38; 95% CI, 1.55-3.54). The overall IR for female athletes was 0.112 compared with 0.063 for males. After adjustment for sport and level of play, females were more than twice as likely to have a first-time ACL injury compared with males (RR, 2.10; 95% CI, 1.34-3.27). With lacrosse as the reference group, risk of first-time noncontact ACL injury was significantly higher for soccer players (RR, 1.77) and for rugby players (RR, 2.23), independent of level of play and sex.

Conclusion: An athlete's risk of having a first-time noncontact ACL injury is independently influenced by level of competition, the participant's sex, and type of sport, and there are no interactions between their effects. Female college athletes have the highest risk of having a first-time noncontact ACL injury among the groups studied.

Keywords: anterior cruciate ligament | ACL | injury | first-time | noncontact | incidence | rate | epidemiology

Article:

It is estimated that anterior cruciate ligament (ACL) injuries affect more than 120,000 athletes in the United States each year, with many of these injuries occurring in young athletes between 15 and 25 years of age.[12,15,33] These injuries are frequently disabling and often painful. They result in time lost from sports, usually require surgery, and are associated with early onset osteoarthritis of the knee, regardless of the type of treatment.[8,22,31,34] Several previously published studies report that the ACL injuries associated with athletics are due primarily to noncontact mechanisms.[2,4,20,26,27] However, a 2007-2012 study of 9 sports at 100 US high schools by Joseph et al[18] reported 58.8% of ACL injuries were due to contact mechanisms.

Using the National Collegiate Athletic Association Injury Surveillance System (NCAA ISS), many studies have evaluated ACL injury incidence rates for both male and female collegiate sports. However, most of this work has combined injuries produced by both noncontact and contact mechanisms and/or individuals who have had their first ACL injury with those who have had repeated injuries of the same kind.[1,3,6,7,14,17,25] Fewer studies have looked at the ACL injury rates for both male and female high school athletes.[18,24,34] Powell and Barber-Foss[29] studied ACL surgery rates, rather than injury rates, for male and female high school soccer and basketball players and found that female players were, respectively, 3.41 and 4.15 times more likely to undergo ACL surgery than were male players.

The ACL injury rate for female athletes is often reported as being 2 to 8 times higher than the rate for male athletes in the same sport at the same level of competition.[2,9,23,30] These estimates have come from univariate analysis, and consequently it is unclear whether the magnitude of the increased risk for females differs significantly between sports or different levels of competition.[1,3,13,17,18,25,34] There is also little agreement as to which sports and what level of competition place an individual at high risk for noncontact ACL injury.[30] In 2007, Prodromos et al[30] published a meta-analysis of the incidence of ACL tears for male and female athletes participating in a range of sports. On the collegiate level, they reported the following range of injury rate ratios showing females more likely to have ACL injury than males: 4 basketball studies, 3.50 to 5.33; 4 soccer studies, 2.38 to 9.63; 1 lacrosse study, 1.06; and 1 rugby study, 1.94.[1,2,13,25,30] Prodromos et al[30] documented only 1 study comparing male and female high school athletes,[24] which reported that the ACL injury rate in female basketball players exceeded the male rate by 4.5 times. More recently, Joseph et al[18] reported that the ACL injury rate for females was 3.4 times higher than that for males across the sex-comparable high school sports of soccer, basketball, and baseball or softball.

The purpose of this study was to determine the incidence rates of first-time noncontact ACL injuries for individual high school and college sports. Our second purpose was to examine how level of competition (college or high school), sport (soccer, basketball, lacrosse, field hockey, football, rugby, volleyball), and participant's sex influence the risk of first-time noncontact ACL injury. Our hypothesis was that these risk factors are independently associated with risk of ACL injury. Third, we collected exposure data with retrospective and prospective approaches and compared how these 2 data collection methods influenced ACL injury rates.

Methods

This was a descriptive epidemiology study that was conducted within a larger study of first-time noncontact ACL injuries in college and high school athletes.[10,32] The University of Vermont Committee on Human Research in the Medical Sciences Review Board approved this study and did not require signed informed consent.

Sport Teams Studied

The following collegiate-level sports were included in our study: men's soccer (MSOC), men's basketball (MBB), men's lacrosse (MLAX), men's football (MFB), men's rugby (MRUG), women's soccer (WSOC), women's basketball (WBB), women's lacrosse (WLAX), women's field hockey (WFH), women's rugby (WRUG), and women's volleyball (WVB). Sports included at the high school level were boys' soccer (BSOC), boys' basketball (BBB), boys' lacrosse (BLAX), boys' football (BFB), girls' soccer (GSOC), girls' basketball (GBB), girls' lacrosse (GLAX), and girls' field hockey (GFH).

Participating Institutions

All colleges and high schools in the state of Vermont were contacted and included in the study if a coach, athletic trainer, or athletic director agreed to provide seasonal first-time noncontact ACL injury data to the research team. From fall 2008 through spring 2012, data were collected from 8 colleges and 18 high schools located in Vermont. Collegiate data included the fall sports of MSOC, MFB, MRUG, WSOC, WFH, WRUG, and WVB at 6 colleges; winter sports of MBB and WBB at 8 colleges; and spring sports of MLAX and WLAX at 7 colleges (Appendix Table A1, available at http://ajsm.sagepub.com/supplemental). All collegiate sports were played at the varsity level, except for the club sports of MRUG, WRUG, and 2 of the 6 WLAX teams in the 2009 season. High school data were collected for varsity, junior varsity, and freshman teams and included the fall sports of BSOC, BFB, GSOC, and GFH at 18 high schools; winter sports of

BBB and GBB at 18 high schools; and spring sports of BLAX and GLAX at 14 high schools (Appendix Table A2, available online).

Collection of Exposure and Injury Data

A person-day of athlete exposure was defined as 1 athlete's participation in a practice or game where he or she was exposed to the possibility of an athletic injury.[14] The total number of person-days of athlete exposure (AE) was measured retrospectively for all teams in the study. For the college teams, we determined the number of games and practices from the first official day of preseason practice to the last postseason game for each team using the appropriate NCAA or club website. Each college team's roster and game schedule, including any postseason games, was obtained from their college website. Each team's games were then marked on separate calendars and the allowed number of practices filled in for each week. The number of players on the team roster was multiplied by the total number of practices and games to determine team AEs.

For retrospective high school AE collection, we determined the first official day of preseason practice to the last postseason game for each high school team using the athletic association website. Each high school team's roster and game schedule was obtained from their high school website. All games for each team were then marked on separate calendars and the allowed number of practices filled in for each week. To determine team AEs, the number of players on the team was multiplied by the total number of practices and games.

To assess the accuracy of collecting exposure data retrospectively, we prospectively collected exposure data from a subgroup of 5 colleges for MSOC, MBB, MLAX, WSOC, WBB, WLAX, and WFH and 6 high schools for BSOC, BBB, BLAX, GSOC, GBB, GLAX, and GFH during 5 sport seasons (winter 2009-2010 through spring 2011). We created an exposure questionnaire on SurveyMonkey (SurveyMonkey, Inc; www.surveymonkey.com; Appendix Figure A1, available online). A coach or player from each team in the subgroup entered the exposure data for each day of their team's season. The assigned coach or player was instructed that an athlete exposure was defined as 1 athlete's participation in 1 practice or game,[14] that a scrimmage was considered a game, and that game warm-ups did not count as participation. The coach or player received a daily e-mail from a designated member of our research group that contained a link to that day's SurveyMonkey exposure questionnaire. The coach or player then entered the team exposure data (total number of players actually participating) for that day or noted zero for "number of players participating" if there was no practice or game (Appendix Figure A1). If a survey was not completed by the next day, a follow-up e-mail was sent the day after to obtain exposure data. The total number of person-days of exposure for the team was then obtained by summing the number of athletes participating in each practice and game.

For the purpose of this investigation, a reportable first-time noncontact ACL injury was defined as a complete grade 3 disruption of the ligament in a person with no previous ACL injury to either leg, occurring as a result of participation in an organized collegiate or high school practice or game and not involving any direct contact to the knee from external forces such as those produced by equipment, other athletes, or the ground. These data were collected over the course of the season by the study coordinator through weekly communication with the individual (athletic trainer, athletic director, or coach) associated with each sport at each institution. Secondary methods of data collection were used to ensure that we identified all noncontact ACL injuries. We held research meetings at the beginning of each year for those responsible for identifying ACL-injured individuals at each institution, and then we visited each institution during the preseason to maintain a presence with those responsible for collecting exposure and injury data. In addition, spot checks were made at all institutions involved in the study over the course of each season to confirm that we were acquiring an accurate measure of exposure and identifying all ACL-injured participants. A standard set of questions was asked to determine the mechanism of injury and whether the injury was a first-time injury to the ACL or repeat injury of an ACL graft. All patients who had a grade 3 injury underwent reconstruction, and consequently the ACL injuries included in the study were confirmed via subsequent arthroscopic visualization at the time of surgery.

Statistical Methods

Injury incidence rates (IRs) were obtained by dividing the number of injuries by person-days of AE, and their 95% CIs were computed based on the Poisson distribution. Poisson regression was used to estimate the relative risk for injury associated with participant sex, type of sport, and level of play after adjustment for the other 2 factors. For example, when analyzing the effect of participant sex on ACL injury rates, we adjusted for type of sport and level of play. In this analysis, lacrosse was used as the reference category for sport because we had data on male and female lacrosse teams at both high school and college levels, and their IRs were based on large numbers of athlete exposures. The fit of the model was assessed by a χ^2 goodness-of-fit test, and the regression coefficients were used to estimate injury rates for individual sports. Potential interactions between the effects of sex, sport, and level of play were evaluated by adding these to the Poisson regression model and testing for improvement in fit using the Wald statistic. Each 2-way interaction was first assessed individually, then in combination, and finally the saturated model with a 3-way interaction was evaluated. Linear regression was used to assess the relationship between the retrospectively and prospectively collected AE data. Using person-days of exposure for each team, prospective AE was regressed on retrospective AE, sport, participants' sex, level of play, and their interactions. The resulting regression equation was used to correct the retrospective exposure data, which were then used to correct the injury rate estimates obtained from the Poisson regression.

Results

The incidence rates of first-time noncontact ACL injury observed in athletes participating in specific sports at both the high school and collegiate levels are shown in Table 1. The IRs were generally higher for females compared with males and for college athletes compared with high school athletes. These differences were also evident when rates were aggregated across participant sex, level of play, and type of sport and were confirmed by the adjusted relative risk (RR) estimates obtained from Poisson regression (Table 2). After adjustment for differences in the distributions of sports and levels of play, females were more than twice as likely as males to have a first-time noncontact ACL injury (RR, 2.10; 95% CI, 1.34-3.27). Similarly, college athletes had a significantly higher injury risk than did high school athletes after adjustment for sport and sex (RR, 2.38; 95% CI, 1.55-3.64). Compared with athletes on lacrosse teams, risk of first-time noncontact ACL injury was significantly higher among those playing soccer (RR, 1.77; 95% CI, 1.04-3.01) and rugby (RR, 2.23; 95% CI, 1.01-4.94) after adjustment for sex and level of play. Injury risk for the other sports did not differ significantly from lacrosse. There were no significant interactions between the effects of participant sex, level of play, and sport, indicating that the effects of these 3 risk factors are independent.

Table 1 Rates of First-Time Noncontact ACL Injury Among Athletes Participating in College and High School Sports[a]

	College				High School			
Sport	Person-Days of Exposure	No. of ACL Injuries	Injury Rate per 1000 Person-Days	95% CI	Person-Days of Exposure	No. of ACL Injuries	Injury Rate per 1000 Person-Days	95% CI
Male								
Soccer	30,241	6	0.198	0.073-0.432	117,140	3	0.026	0.006-0.075
Basketball	38,927	2	0.051	0.006-0.186	108,622	4	0.037	0.010-0.094
Lacrosse	71,731	6	0.084	0.031-0.182	121,583	7	0.058	0.023-0.119
Football	18,417	3	0.163	0.035-0.476	144,233	8	0.055	0.024-0.109
Rugby	17,886	3	0.168	0.036-0.490				
Female								
Soccer	28,115	11	0.391	0.195-0.700	114077	15	0.131	0.074-0.217
Basketball	34,882	5	0.143	0.047-0.335	98,296	6	0.061	0.022-0.133
Lacrosse	37,567	4	0.106	0.029-0.273	86,160	6	0.070	0.026-0.152
Field hockey	25,993	1	0.038	0.001-0.214	82,946	4	0.048	0.013-0.123
Rugby	14,723	6	0.408	0.150-0.887				

Volleyball	2237	1	0.447	0.011-2.491	

[a]ACL, anterior cruciate ligament.

Table 2 First-Time Noncontact ACL Injury Rates and Relative Risks Associated With Sex, Level of Play, and Sport[a]

	Person-Days of Exposure	No. of ACL Injuries	Injury Rate per 1000 Person-Days	95% CI	Relative Risk (Adjusted)	95% CI
Sex						
Males	668,780	42	0.063	0.045-0.085	1.00	
Females	524,996	59	0.112	0.086-0.145	2.10	1.34-3.27
Level of play						
High school	873,057	53	0.061	0.045-0.079	1.00	
College	320,719	48	0.150	0.110-0.198	2.38	1.55-3.64
Sport						
Soccer	289,573	35	0.121	0.084-0.168	1.77	1.04-3.01
Basketball	280,727	17	0.061	0.035-0.097	0.84	0.45-1.57
Lacrosse	317,041	23	0.073	0.046-0.109	1.00	
Field hockey	108,939	5	0.046	0.015-0.107	0.47	0.18-1.27
Football	162,650	11	0.068	0.034-0.121	1.68	0.78-3.63
Rugby	32,609	9	0.276	0.126-0.524	2.23	1.01-4.94
Volleyball	2237	1	0.447	0.011-2.491	2.57	0.34-19.38

[a]ACL, anterior cruciate ligament.

To assess the fit of the Poisson regression model that was used to obtain adjusted relative risk estimates, the regression coefficients for sports, levels of play, and male or female sex were used to predict the number of injuries occurring in each individual sport. For most sports, the observed and predicted values were very similar (Table 3). For high school male athletes, the predicted number of injuries was somewhat higher than the observed number for soccer (7.2 vs 3) and lower than the observed value for lacrosse (4.2 vs 7), but neither of these differences was statistically significant (P = .12 and P = .18, respectively). The overall χ^2goodness-of-fit test indicated that the Poisson regression model fit the observed rates very well (P = .62). The injury rates estimated from the model (Table 3) are therefore more informative than observed raw rates presented in Table 1 because they are less heavily affected by random variation.

Table 3 First-Time Noncontact ACL Injury Rate Estimates Based on Poisson Regression Results and Corrected Exposure-Days[a]

	ACL Injuries		Person-Days of Exposure		Estimated Injury Rate per 1000 Person-Days of Exposure			
Sport	Observed	Estimated	Original[b]	Corrected[c]	Original	95% CI	Corrected	95% CI
Male college								
Soccer	6	4.4	30,241	23,747	0.146	0.087-0.245	0.186	0.111-0.312
Basketball	2	2.7	38,927	30,568	0.070	0.038-0.127	0.089	0.049-0.161
Lacrosse	6	5.9	71,731	56,328	0.083	0.050-0.138	0.105	0.063-0.176
Football	3	2.6	18,417	14,462	0.139	0.071-0.273	0.177	0.090-0.348
Rugby	3	3.3	17,886	14,045	0.185	0.091-0.376	0.235	0.115-0.479
Female college								
Soccer	11	8.6	28,115	22,078	0.307	0.195-0.482	0.391	0.249-0.614
Basketball	5	5.1	34,882	27,392	0.146	0.084-0.253	0.186	0.108-0.322
Lacrosse	4	6.5	37,567	29,500	0.174	0.106-0.285	0.221	0.135-0.363
Field hockey	1	2.1	25,993	20,411	0.082	0.033-0.204	0.105	0.042-0.260
Rugby	6	5.7	14,723	11,561	0.387	0.197-0.759	0.493	0.251-0.967
Volleyball	1	1.0	2237	1757	0.447	0.063-3.173	0.569	0.080-4.041
Male high school								
Soccer	3	7.2	117,140	91,986	0.062	0.038-0.099	0.078	0.049-0.126
Basketball	4	3.2	108,622	85,297	0.029	0.016-0.053	0.037	0.021-0.067
Lacrosse	7	4.2	121,583	95,475	0.035	0.020-0.594	0.044	0.026-0.076
Football	8	8.4	144,233	113,261	0.059	0.032-0.106	0.075	0.041-0.136
Female high school								
Soccer	15	14.7	114,077	89,580	0.129	0.087-0.192	0.164	0.111-0.244

Basketball	6	6.0	98,296	77,188	0.061	0.036-0.105	0.078	0.046-0.133
Lacrosse	6	6.3	86,160	67,658	0.073	0.044-0.121	0.093	0.056-0.154
Field hockey	4	2.9	82,946	65,134	0.035	0.014-0.095	0.044	0.018-0.108

[a]ACL, anterior cruciate ligament. [b]Retrospectively calculated by multiplying the number of athletes on each team by the number of games and practices. [c]Exposure days calculated as follows: corrected = 0.785 3 original person-days.

Both the observed and estimated injury rates are likely to be lower than the true rates because person-days of exposure were obtained retrospectively by multiplying the number of athletes on a team by the number of practices and games held during the season. Comparison of retrospective and prospective data collected on a subset of teams indicated that they were highly correlated ($R^2 = 0.81$), but the retrospective method consistently overestimated a team's AEs by 27%. The relationship did not differ significantly between male and female teams, type of sport, or level of play. The retrospective exposure data were therefore multiplied by 0.785 (the slope estimate from the regression equation) to obtain a corrected number of AEs for each sport, and this was then used to correct the injury rate estimates obtained from the Poisson regression (Table 3). This correction does not affect the relative risk estimates presented in Table 2.

Discussion

This investigation confirmed our hypothesis that athletes' sex, the type of sport they participate in, and their level of competition (high school or college) are independently associated with the risk of having a first-time noncontact ACL injury. This study of first-time noncontact ACL injury incidence rates included both male and female athletes participating in a number of different sports at the college and high school levels. However, unlike previous studies that either compared female with male athletes in specific sports or combined data across sports,[‖] we used Poisson regression to simultaneously estimate the effects of sex (male vs female), level of play (college vs high school), and type of sport. The numbers of injuries predicted by our Poisson regression model, which included these 3 risk factors and no interactions, were very similar to the observed numbers for male and female sport teams at the high school and college levels. This provides compelling evidence that the relative risk of first-time noncontact ACL injury among females, compared with males, is of similar magnitude regardless of the sport or levels of play being examined. Similarly, the increase in relative risk among collegiate athletes compared with high school athletes is independent of participant sex and type of sport they participate in, while the increased relative risk associated with some sports is independent of sex and level of play.

This study focused on high school and college athletes because they comprise a large proportion of ACL injuries. It also had a unique concentration of first-time noncontact injury because this is a very common injury mechanism in these athletes, and we wanted to understand the combined effects of participant sex, level of play, and sport on this type of injury. It may be that these factors have an entirely different influence on ACL injuries produced by contact mechanisms, and it is very unlikely that their effects are independent because degree of contact varies with sport and level of competition, as well as between male and female sports. Similarly, repeated injury may not have the same relationship to sex, sport, and level of play as first-time injury, and it is influenced by the severity of the initial injury, the treatment received, and the healing response. It would therefore not be meaningful to perform an analysis on combined data from contact and noncontact injuries or first-time and repeat injuries.

We included high school varsity, junior varsity, and freshman sports teams so that our results would be applicable to all students participating in high school athletics and to avoid ambiguity about our population of inference. These team categorizations do not always closely correspond to the level of play because of differences in school size and competitive divisions. In addition, it is not uncommon for nonvarsity players to be added to varsity rosters during a sport season, and sometimes varsity and junior varsity teams practice together. Overall, high school athletes on junior varsity teams had a lower incidence rate than did varsity athletes (0.018 vs 0.083 per 1000 person-days of athlete exposure). There were no first-time noncontact ACL injuries among athletes on freshman teams, but their person-days of exposure were much lower, comprising only 2.9% of all high school athlete exposures. These data are difficult to interpret because of small sample sizes, which precluded adjustment for differences in participant sex and sports among varsity, junior varsity, and freshman teams. However, they are consistent with our finding that the incidence of noncontact ACL injury risk increases with increasing level of competition.

We obtained an adjusted relative risk of 2.10 for female compared with male athletes, supporting previous findings of a substantially higher incidence rate of ACL injury in females than in males. We found a similarly increased injury risk in collegiate athletes compared with high school athletes (RR, 2.38), independent of athletes' sex and the sport in which they participated. The risk of first-time noncontact ACL injury was also significantly higher for soccer and rugby players than for lacrosse players, independent of participant sex and level of play. We repeated the analysis with soccer as the reference sport and found that basketball and field hockey players had a significantly lower risk of ACL injury than did soccer players. Volleyball, studied only at the women's collegiate level, had an adjusted relative risk of 2.57 compared with lacrosse but a large 95% CI (0.34-19.38) because it was based on only 1 injury in 2237 athlete exposures. Hootman et al[17] reported a women's volleyball ACL injury rate of 0.09 per 1000 athlete exposures, while Prodromos et al[30] in their meta-analysis reported on 2 high school girls' volleyball studies[16,28] with total exposures of 28,657 and no torn ACLs.

Comparison of ACL injury rates in the literature is problematic due to variations in exposure data collection methods, injury definition and identification, and study design. In 2006, Knowles et al[19] urged researchers to use a checklist of items to document sports injury data (eg, definition of injury, who collected the injury data and when they were collected, how time at risk was defined, and who collected time at risk data and when they were collected), because in the past authors have not reported their methods in sufficient detail to allow comparisons of ACL injury incidence rates. Caine et al[5] state that given these methodologic shortcomings and study differences, it is useful to compare incidence rates across sports within a multiple-sport study that has used the same injury definition and data collection methods across sports.

In this study, we strove to follow the most widely reported injury data collection methods and to report those methods in detail. We studied only first-time noncontact ACL injuries across multiple sports, while many studies of single or multiple sports do not differentiate between first-time and repeat injuries and/or noncontact versus contact ACL injuries.[¶] We did not collect information about repeat ACL injuries and ACL injuries produced by contact mechanisms, but our incidence rates would have been higher if they were included. We also used results from Poisson regression to obtain estimates of injury incidence rates for individual male and female sports at the high school and college levels, which are less dependent on sampling error than the observed rates. Appendix Table A3 (available online) allows the comparison of these estimates with the incidence rates reported in other studies. On the collegiate level, we reported IRs of 0.186 per 1000 AEs for women's basketball, lower than 7 other studies, and 0.186 for men's soccer, higher than 7 other studies. There were fewer studies for comparison on the high school level. We reported IRs of 0.075 for boys' football, lower than 3 other studies, and 0.078 for girls' basketball, lower than 4 other studies.

A limitation of this study is relying on the accuracy of the information gathered from the college and high school websites. A second limitation is the calculation of athlete exposure. The strictest calculation would prospectively record the number of minutes played for each athlete on a team. The effort required to do this made it prohibitive for a large study that involved multiple schools. Therefore, we used a common definition of exposure (the participation of 1 athlete in 1 practice or game where he or she is exposed to the possibility of an athletic injury) to retrospectively calculate AE. Inherent limitations of this retrospective calculation method are the assumptions that all players participated in every game and practice (which is not accurate due to reserve players, injuries, and illnesses) and that each team held every allowed practice. Therefore, we also prospectively collected person-days of athlete exposure for a subset of teams and found that the retrospective method consistently overestimated a team's athlete exposure by about 27%. Correction for this discrepancy increased the injury rate estimates but did not affect the relative risk estimates. To our knowledge, this is the only study to compare the results of retrospective and prospective athlete exposure data collection on the same population.

In addition, it was not within the scope of this epidemiologic study to distinguish between injuries that occurred during practices or games, or injuries that occurred on different playing surfaces, nor did it take into account which teams, if any, offered an injury prevention training program. Last, although our sample population was geographically representative, it may not be nationally representative. For example, it may be that the data collected from our geographic region are not representative of other regions throughout North America that have participants with different ethnic backgrounds or athletes who take part in sports with different environmental conditions, levels of training, skill development, expertise, and so on.

To our knowledge, this is the only study to date to look at first-time noncontact ACL injuries, which present the greatest opportunity for preventive intervention, across the collegiate and high school levels, in both sexes, and across multiple sports. It is also the first study to jointly examine the effects of sex, level of play, and sport on ACL injury risk, and the results indicate that these factors act independently to influence the risk of first-time noncontact ACL injury.

Footnotes

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- ‖ References 1, 3, 13, 14, 17, 18, 24, 25, 28, 34.
- ¶ References 1, 3, 6, 7, 11, 14, 17, 21, 23 ⇓ ⇓-26, 34.

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