

Epidemiology of Recurrent Anterior Cruciate Ligament Injuries in National Collegiate Athletic Association Sports

The Injury Surveillance Program, 2004-2014

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Background: An anterior cruciate ligament (ACL) rupture is a serious injury that can be career-ending in collegiate athletics. A rerupture after primary ACL reconstruction occurs in 1% to 11% of all athletes.

Purpose: To describe the epidemiology of recurrent ACL ruptures in the 25 National Collegiate Athletic Association (NCAA) sports in the NCAA Injury Surveillance Program (ISP) and to identify and compare sport-specific risk factors for a recurrent ACL rupture.

Study Design: Descriptive epidemiology study.

Methods: Athletes who experienced a primary or recurrent ACL rupture between 2004 and 2014 were identified using data from the NCAA ISP. ACL ruptures occurred in 12 of 25 sports during the study period. We assessed the rates and patterns of primary and recurrent ACL ruptures and reported them as events per 10,000 athlete-exposures (AEs). Sex-comparable sports were compared using rate ratios. Rupture rates were compared using odds ratios, with *P* values < .05 indicating significance. Regular-season and postseason data were combined because of low counts of postseason events.

Results: Of 350,416 AEs, there were 1105 ACL ruptures, 126 of which were recurrent. The highest rates of recurrent ACL ruptures (per 10,000 AEs) were among male football players (15), female gymnasts (8.2), and female soccer players (5.2). Of sports played by athletes of both sexes, women's soccer had a significantly higher rate of recurrent ACL ruptures than men's soccer (rate ratio, 3.8 [95% CI, 1.3-15]). Among all sports, men had a significantly higher rate of recurrent ACL ruptures (4.3) than women (3.0) (*P* = .04). Overall, the ratio of recurrent to primary ACL ruptures decreased over the 10-year study period. Both women and men had a decreasing trend of recurrent to primary ACL ruptures, although women had a steeper decrease.

Conclusion: These data can help identify athletes who are most at risk of recurrent ACL ruptures after ACL reconstruction and who may benefit from injury prevention programs.

Keywords: anterior cruciate ligament; Injury Surveillance Program; National Collegiate Athletic Association; primary rupture; recurrent rupture

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Anterior cruciate ligament (ACL) ruptures are among the most commonly studied injuries in orthopaedic research. The incidence of ACL ruptures is estimated to range from 30 to 78 per 100,000 person-years.^{5,13,15,18,27,28,37} After ACL reconstruction, 61% to 89% of athletes successfully return to sports,^{8,26,30,39} typically at 8 to 18 months after reconstruction, depending on the level of play.^{26,29,30} An analysis of National Collegiate Athletic Association (NCAA) Injury Surveillance Program (ISP) data from 1988 to 2004 showed that the highest rates of ACL ruptures occurred in women's gymnastics, women's basketball, women's soccer, and men's football.¹⁷ Using ISP data, a recent study compared the rate of ACL ruptures during the period 1988-2004 with 2004-2013; the authors found an 88% decrease in ACL

ruptures among female gymnasts, a 64% decrease among female soccer players, and modest decreases among male football players and female basketball players.¹

After primary ACL reconstruction, a rerupture can be devastating. The reported rate of ACL reruptures range from 1% to 11%.⁸ Reruptures may be caused by traumatic reinjuries, biologic graft failure, or technical surgical errors.^{9,36} A large prospective multicenter study showed that the most common cause of a rerupture is a noncontact injury to the ACL graft, which constitutes 55% of reruptures treated with revision ACL reconstruction.⁹ Because of the high costs of surgery and rehabilitation and the substantial time needed for rehabilitation, primary and recurrent ACL ruptures represent a major economic burden^{10,16} and may end the careers of college athletes. Compared with NCAA athletes who begin their collegiate careers with surgery-naïve knees, those who have undergone knee surgery before college matriculation have a significantly higher rate of repeat ipsilateral knee surgery during their collegiate athletic careers, but this rate has not been previously analyzed by sex or sport.^{21,43}

Despite the physical and economic burdens of ACL reruptures, there are few current epidemiological data on such injuries among college athletes. The aim of this study was to describe the epidemiology of recurrent ACL ruptures in NCAA championship sports using data from the ISP and to compare the risk factors for a recurrent ACL rupture by sport, player sex, event type (practice vs competition), and season (preseason vs regular season/postseason).

METHODS

This study was deemed exempt from institutional review board approval.

Data Collection

ACL rupture data were obtained from the ISP database for the 2004-2005 to 2013-2014 academic years for 25 men's and women's collegiate sports.²² The ISP data collection methods have been described.²² The ISP includes 25 sports from each of 3 competitive divisions. Athletic trainers log the number of student-athletes participating in each school-sanctioned practice or competition as well as injuries sustained. This does not include injuries sustained outside of sanctioned events, practices, and competitions. Data are reported using an electronic health record application by the medical staff throughout the academic year as part of daily clinical practice. Data are then transferred to the Datalys Center for Sports Injury Research and Prevention's server, where identifying information is removed and relevant variables and values are retained and released.²²

Deidentified common data elements are extracted and subjected to an automated verification process. Data that are flagged as inconsistent or invalid are reassessed by the athletic trainers and quality-assurance staff, who work together

to resolve all issues. A reportable injury is defined as one resulting from participation in an organized intercollegiate practice or competition that required attention from a physician or athletic trainer. A reportable athlete-exposure (AE) is defined as 1 athlete participating in 1 NCAA-sanctioned practice or competition in which the athlete was exposed to the possibility of an injury, regardless of the duration of the athlete's participation. Only athletes with playing time during a competition are included in competition exposures.²²

Primary ACL ruptures were defined as those occurring in knees with no history of ACL ruptures. Recurrent ACL ruptures were defined as those occurring in the same knee as a previously treated ACL rupture.

Statistical Analysis

The rates and patterns of ACL ruptures during sanctioned collegiate sporting events were analyzed. The numbers of primary and recurrent ACL ruptures per 10,000 AEs were stratified by sport, event (practice vs competition), and season (preseason, regular season, or postseason). Because of low postseason event counts, rate ratios (RRs) comparing rates between the preseason and the combined regular season and postseason were assessed. RRs (with 95% CIs) were calculated to compare primary versus recurrent ACL rupture rates, preseason versus regular-season/postseason rates, practice versus competition rates, and rates by sport. The rate was calculated using the number of ACL ruptures and number of AEs by sport and is reported as number per 10,000 AEs. For sex-comparable sports (eg, men's and women's basketball), rates were compared between sexes by calculating RRs and using odds ratios (ORs) to examine differences between primary versus recurrent ACL ruptures. We were unable to make this comparison using preseason ice hockey and soccer data because of the absence of recurrent ACL ruptures among female ice hockey players and male soccer players during the preseason.

Data on primary and recurrent ACL ruptures were stratified by academic year and sex. The ratio of recurrent to primary ACL ruptures among men's and women's sports was also calculated by year, and a linear regression best-fit model was used to determine the trend of change in the ratio of recurrent to primary ACL ruptures during the 10-year study period.

We evaluated the risk factors for a recurrent ACL rupture among NCAA athletes and calculated ORs to assess whether season (preseason vs regular season/postseason) or event type (practice vs competition) was associated with a recurrent ACL rupture. These data were further stratified by sex.

All 95% CIs not containing 1.0 were considered statistically significant. ORs were considered significant if $P < .05$. Data were analyzed using MedCalc software (version 17.5.5; MedCalc Software).

RESULTS

Overall Frequencies and Rates

The following 12 sports had athletes who sustained ACL ruptures: men's and women's basketball, ice hockey,

⁸References 3, 4, 6, 8, 25, 26, 33, 39, 40, 44.

TABLE 1
Rate of Anterior Cruciate Ligament Ruptures by Sport^a

Sport	All Rupture	Primary Rupture	Recurrent Rupture
Basketball			
Men's	11 (8.6-14)	9.6 (7.4-12)	1.4 (0.7-2.6)
Women's	27 (23-31)	24 (21-29)	2.6 (1.6-4.1)
Gymnastics (women's)	34 (23-50)	26 (16-40)	8.2 (3.3-17)
Ice hockey			
Men's	8.3 (5.2-13)	7.4 (4.5-12)	0.9 (0.1-3.2)
Women's	4.5 (1.7-10)	4.5 (1.7-10)	0.0 (0.0-0.0)
Field hockey (women's)	21 (13-31)	16 (9.8-26)	4.1 (1.3-9.9)
Football (men's)	152 (139-165)	137 (125-149)	15 (11-19)
Lacrosse			
Men's	42 (31-55)	39 (29-52)	2.6 (0.7-7.1)
Women's	44 (34-56)	39 (30-51)	3.6 (1.3-8.1)
Soccer			
Men's	9.5 (6.4-14)	8.1 (5.3-12)	1.4 (0.4-3.3)
Women's	22 (18-28)	17 (13-22)	5.2 (3.2-7.9)
Volleyball (women's)	8.3 (5.9-11)	7.4 (5.2-10)	0.9 (0.3-2.2)

^aData are shown as number of ruptures per 10,000 athlete-exposures (95% CI).

lacrosse, and soccer; men's football; and women's field hockey, gymnastics, and volleyball. During the study period, 1105 ACL ruptures (979 primary and 126 recurrent) and 350,416 AEs were reported, for a rupture rate of 32 per 10,000 AEs. One athlete was excluded because of a lack of ACL injury data. Of all ACL injuries, 126 (11%) were recurrent. Most of the recurrent ACL ruptures occurred in men's football (41%, $n = 52$), women's soccer (15%, $n = 19$), and women's basketball (13%, $n = 17$). The highest rates (per 10,000 AEs) of recurrent ACL ruptures were in men's football (15), women's gymnastics (8.2), and women's soccer (5.2) (Table 1).

During the study period, the ratio of recurrent to primary ACL ruptures decreased by 0.85% per year (Figure 1). This decrease was steeper among women than among men, but this difference was not statistically significant ($P = .814$).

Sport-Specific Analyses

Men's and Women's Basketball. There was no significant difference in the rate of recurrent ACL ruptures by sex ($P = .12$) (Table 2) or in the rate of ACL ruptures by competition versus practice or preseason versus regular season/postseason. Both women and men were more likely to sustain ACL ruptures during competition than during practice, with no significant differences in the rupture rate during the preseason versus regular season/postseason (Table 3).

Men's and Women's Ice Hockey. Among ice hockey players, there were no significant differences between men and women in primary or recurrent ACL ruptures (Table 2). Both women and men were more likely to sustain ACL ruptures during competition versus practice and during the regular season/postseason versus preseason (Table 3).

Men's and Women's Lacrosse. Among lacrosse players, there were no significant differences in the rate of primary or recurrent ACL ruptures between men and women (Table 2). Both women and men were more likely to sustain ruptures during competition versus practice, and women were more likely to sustain ruptures during the regular season/postseason versus preseason (Table 3).

Men's and Women's Soccer. Women were more likely than men to sustain recurrent ACL ruptures (RR, 3.8 [95% CI, 1.3-15]) (Table 2). Women were also more likely to sustain recurrent ACL ruptures during practice (RR, 11 [95% CI, 1.6-447]) but not during competition, the preseason, or the regular season/postseason. Both women and men were more likely to sustain ACL ruptures during competition than during practice, and men were more likely to sustain ACL ruptures during the regular season/postseason versus preseason (Table 3).

Men's Football. The overall rate of ACL ruptures was 152 (95% CI, 139-165) per 10,000 AEs, of which there were 15 recurrent ACL ruptures (95% CI, 11-19) per 10,000 AEs. During competition, there were 568 ACL ruptures (95% CI, 503-640) per 10,000 AEs, which was much higher than the practice rate (88/10,000 AEs [95% CI, 78-99]) (OR, 6.8 [95% CI, 5.7-8.1]; $P < .0001$). The ACL rupture rate was similar during the preseason (151/10,000 AEs [95% CI, 129-176]) versus regular season/postseason (158/10,000 AEs [95% CI, 143-175]) (OR, 1.1 [95% CI, 0.9-1.3]; $P = .61$) (Table 3).

Women's Field Hockey. The overall rate of ACL ruptures was 21 (95% CI, 13-31) per 10,000 AEs, of which there were 4.1 recurrent ACL ruptures (95% CI, 1.3-9.9) per 10,000 AEs. The rate of ACL ruptures during competition (34/10,000 AEs [95% CI, 17-62]) was more than double the rate during practice (16/10,000 AEs [95% CI, 8.2-27]) (OR, 2.2 [95% CI, 0.9-5.2]; $P = .09$). The rate of ACL ruptures during the preseason (33/10,000 AEs [95% CI, 15-62]) was approximately double the rate during the regular season/postseason (16/10,000 AEs [95% CI, 8.9-23]) (OR, 0.5 [95% CI, 0.2-1.2]; $P = .13$) (Table 3).

Women's Gymnastics. There were 25 ACL ruptures in women's gymnastics (19 primary, 6 recurrent) during the 10-year study period. The overall rate of ACL ruptures was 34 (95% CI, 23-50) per 10,000 AEs, of which there were 8.2 recurrent ruptures (95% CI, 3.3-17) per 10,000 AEs. The rate of ACL ruptures during competition (129/10,000 AEs [95% CI, 58-225]) was much higher than the rate during practice (22/10,000 AEs [95% CI, 12-35]) (OR, 6.1 [95% CI, 2.7-13.4]; $P < .0001$). The rate of ACL ruptures during the regular season/postseason (48/10,000 AEs [95% CI, 30-75]) was more than double the rate during the preseason (19/10,000 AEs [95% CI, 8.5-38]) (OR, 2.5 [95% CI, 1.0-6.0]; $P = .04$) (Table 3).

Women's Volleyball. There were 36 ACL ruptures in women's volleyball (32 primary, 4 recurrent) during the 10-year study period. The overall rate of ACL ruptures was 8.3 (95% CI, 5.9-11) per 10,000 AEs, of which there were 0.9 recurrent ruptures (95% CI, 0.3-2.2) per 10,000 AEs. The rate of ACL ruptures during competition (15/10,000 AEs [95% CI, 9.7-23]) was more than twice the rate during practice (6.4/10,000 AEs [95% CI, 3.7-11]) (OR, 2.3 [95% CI, 1.2-4.5]; $P < .0001$). The rate of ACL ruptures did not differ

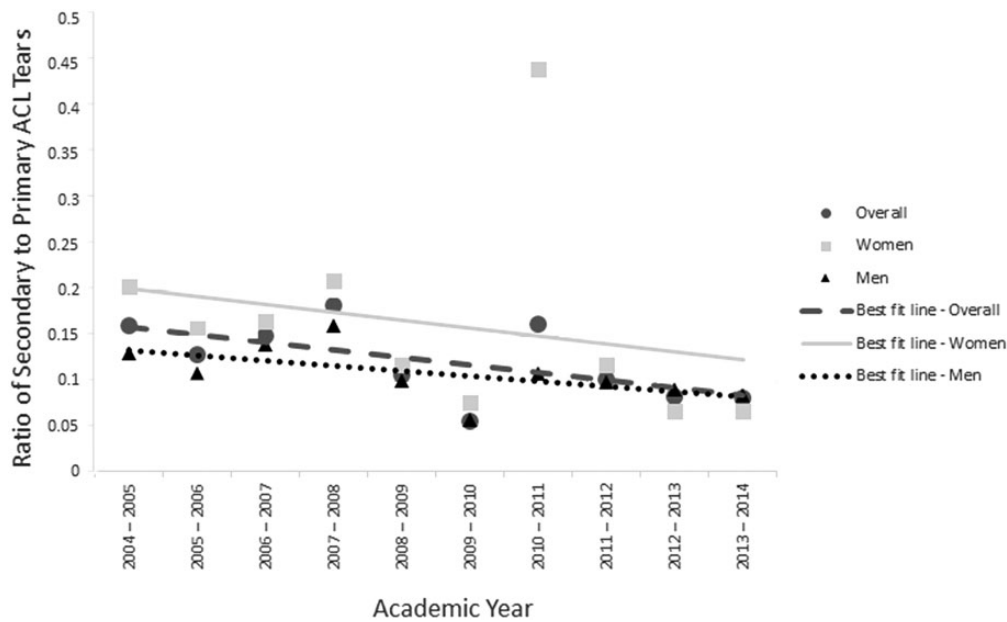


Figure 1. Ratio of recurrent to primary anterior cruciate ligament (ACL) tears by player sex.

TABLE 2
Rate Ratio of Anterior Cruciate Ligament Ruptures in Women Versus Men

Sport	Primary Rupture		Recurrent Rupture	
	Rate Ratio (95% CI)	P Value	Rate Ratio (95% CI)	P Value
Basketball	2.6 (1.9-3.4)	<.0001 ^a	1.9 (0.8-4.3)	.12
Ice hockey	0.6 (0.2-1.7)	.33	0.0 (0.0-8.6)	.57
Lacrosse	1.0 (0.7-1.5)	.99	1.4 (0.3-5.8)	.66
Soccer	2.1 (1.3-3.4)	.0016 ^a	3.8 (1.3-15)	.02 ^a

^aAchieved statistical significance.

significantly during the preseason versus regular season/postseason (Table 3).

DISCUSSION

We examined the epidemiology of recurrent ACL ruptures in 25 NCAA sports, of which 12 had reported ACL injuries. We found that from the 2004-2005 to 2013-2014 academic years, the rate of recurrent ACL ruptures in many sports (men’s football, women’s gymnastics, and women’s field hockey) remained high, with women’s soccer players having a significantly higher rate of recurrent ACL ruptures compared with men’s soccer players.

Studies have reported a high incidence of ACL ruptures,^{5,13,15,18,27,28,37} and recurrent ACL ruptures are potentially career ending. Of professional athletes in the United States who underwent ACL reconstruction, 87% successfully returned to play at a mean 1 year after surgery; however, of the 3.5% who had recurrent ACL ruptures requiring revision surgery, the return-to-play rate was only

50%.⁸ Okoroha et al³¹ reported on National Football League (NFL) players who underwent revision ACL reconstruction between 2007 and 2014. They found that of 24 players who underwent surgery, 19 returned to regular-season NFL play at an average of 1 year after surgery. Those who returned to play in the NFL played in significantly fewer games and seasons after surgery than before their recurrent injury.³¹ Using data from the prospective French ACL Study (FAST), Lefevre et al²³ compared return to sport after primary and revision ACL reconstruction. In this cohort, functional scores at 1 year were significantly better in the primary reconstruction group than in the revision reconstruction group. The return-to-sport rate was similar between the 2 groups; however, those who had undergone revision ACL reconstruction were significantly less likely to return to their usual preoperative sport than those who had undergone primary ACL reconstruction.

In addition to the lower rate of return to sports, recurrent ACL injuries carry a risk of long-term functional deficits. A report of ACL ruptures in an orthopaedic sports medicine practice found that at 12 years after revision reconstruction, approximately 28% of patients had sustained a recurrent rupture of the ACL graft.² Those who had recurrent ACL ruptures had worse International Knee Documentation Committee scores than those with primary ACL reconstructions, with a greater severity of degenerative radiographic changes in the group whose revised ACL reconstructions had reruptured.²

In our study, the highest rates of recurrent ACL ruptures occurred in men’s football, women’s gymnastics, and women’s soccer, whereas the highest rates of primary ACL ruptures occurred in men’s football, men’s and women’s lacrosse, and women’s gymnastics. Previously reported factors associated with a higher risk of recurrent ACL ruptures include higher level of play/level of activity, graft

TABLE 3
Rate of Anterior Cruciate Ligament Ruptures per 10,000 Athlete-Exposures and Odds Ratio of a Rupture Occurring During Competition Versus Practice and Regular Season/Postseason Versus Preseason^a

Sport	Competition vs Practice Rate				Regular Season/Postseason vs Preseason Rate			
	Competition	Practice	OR (95% CI)	P Value	Regular Season/Postseason	Preseason	OR (95% CI)	P Value
Basketball								
Men's	25	6.3	4.0 (2.5-6.5)	<.0001 ^b	6.3	11	1.0 (0.6-1.7)	.86
Women's	64	15	4.4 (3.2-5.9)	<.0001 ^b	15	29	0.9 (0.6-1.3)	.58
Field hockey (women's)	34	16	2.2 (0.9-5.2)	.09	16	33	0.5 (0.2-1.2)	.13
Football (men's)	568	88	6.8 (5.7-8.1)	<.0001 ^b	158	151	1.1 (0.9-1.3)	.61
Gymnastics (women's)	129	22	6.1 (2.7-13.4)	<.0001 ^b	48	19	2.5 (1.0-6.0)	.04 ^b
Ice hockey								
Men's	25	1.8	14 (4.0-48)	<.0001 ^b	1.8	4.3	0.2 (0.1-0.4)	<.0001 ^b
Women's	10	2.5	4.1 (0.7-24)	.12	2.5	0	1.7 (0.1-30)	.73
Lacrosse								
Men's	94	30	6.2 (3.5-11)	<.0001 ^b	30	38	1.2 (0.6-2.2)	.63
Women's	111	25	4.5 (2.9-7.5)	<.0001 ^b	25	26	2.0 (1.1-3.8)	.03 ^b
Soccer								
Men's	25	3.7	6.9 (3.0-16)	<.0001 ^b	3.7	2.7	7.9 (3.0-21)	<.0001 ^b
Women's	48	13	3.8 (2.4-5.8)	<.0001 ^b	13	23	1.0 (0.6-1.6)	.88
Volleyball (women's)	15	6.4	2.3 (1.2-4.5)	<.0001 ^b	6.4	9.7	0.8 (0.4-1.7)	.58

^aOR, odds ratio.

^bAchieved statistical significance.

type, and female sex.^{20,24,38} Our study focused on collegiate athletes; in our study, 1 of 9 ACL ruptures was recurrent. Recurrent ACL ruptures accounted for 14% of ACL ruptures in women and 10% of ACL ruptures in men. All analyzed sports in our study had a higher rate of injuries during competition, except women's ice hockey and women's field hockey in which there were no differences in the rupture rate between competition and practice. This propensity toward ACL ruptures during competition has been reported previously,^{11,12} and it may in part be because of the less predictable environment, greater speed, and greater intensity of competition settings.

Athletes are at greatest risk of sustaining a recurrent ACL rupture at 1 to 2 years after primary surgery.^{3,25,33,35} The Multicenter ACL Revision Study (MARS) found that 55% of those undergoing revision ACL reconstruction for an ACL rerupture had experienced noncontact mechanisms of an ACL rerupture.⁹ Research has shown that female athletes have a higher risk of noncontact ACL ruptures than male athletes, with data from the 2004-2014 NCAA ISP cohort indicating that 60% of ACL ruptures in female athletes were caused by a noncontact injury, versus 41% in male athletes.¹ Compared with their male counterparts, female athletes tend to have insufficiency in neuromuscular control, with an imbalance of flexibility, coordination, and muscle strength that may predispose them to ACL ruptures⁷ as well as reruptures of an ACL graft suggesting the potential need for targeted prevention in return-to-play guidelines.

Within sex-comparable sports, we found a 3.8 times higher rate of recurrent ACL ruptures among women's soccer players compared with men's soccer players. This may be attributable, in part, to a higher rate of primary ruptures among women than among men either during previous seasons or during

high school play before collegiate sport participation.^{1,19} Allen et al³ described ACL injury recurrence among a cohort of female soccer players, in which 11% of athletes of any level of play presenting to their clinic with an ACL rupture had recurrent ACL tears. Furthermore, significantly more athletes who returned to playing soccer had graft tears compared with those who did not return to the sport.³

Overall, our data provide an approximation that from 2004 to 2014, there was a decreasing trend in the ratio of recurrent to primary ACL ruptures. This may be caused by several factors, including data variations in the methods used to calculate this approximation, improvements in surgical fixation techniques, improved surgical indications, the higher baseline ratio of recurrent to primary ACL ruptures among women than men at the beginning of our study period, and the possible effect of injury prevention programs targeting female athletes.^{14,34,41,42} The American Academy of Orthopaedic Surgeons recently published appropriate use criteria for ACL injury prevention programs, stating that for appropriate patients, a supervised rehabilitation program can aid in ACL injury prevention.⁴² Although not studied, it is possible that the implementation of such programs during the 2004-2014 study period may partially account for the decreasing trend observed in the ratio of recurrent to primary ACL ruptures in female athletes compared with male athletes. Further studies on athletes with prior ACL reconstruction should be performed to help determine who may derive the most benefit from injury prevention programs.

Our study has several limitations. The incidence of ACL ruptures during the study period was relatively low, limiting our ability to examine sport-specific differences. Because these are population-level surveillance data, we were unable to account for risk factors that were

unrecorded in the data set. We present estimates of rerupture rates because the ISP data did not allow us to follow individual athletes for rupture recurrence. Additionally, athletes whose primary ACL ruptures occurred during their last season of competition could not be followed for recurrent ACL ruptures. However, these estimates allow us to compare sports and risk factors for a recurrent ACL rupture during play in the NCAA.

To calculate the rupture rate, we used AEs, which are defined in independent units without controlling for duration, intensity, or type of sport exposure. Okorooha et al³² showed that among National Basketball Association athletes, the number of exposures and the amount of time played made equal contributions to ACL injury rates. Because the NCAA ISP data set does not identify all athletes with a history of ACL ruptures but only comments on whether an ACL rupture is primary or recurrent, we used AE data for the entire population in calculating the rate of ACL reruptures. Therefore, we may have underestimated rerupture rates. Unfortunately, no individual identifiers are available in the database, so we were unable to assess the rate of contralateral ACL ruptures in patients with previous ACL ruptures.

Athletes with previous ACL ruptures may not perform at the same level or have the same number of AEs as those with injury-naïve knees, adding to the underestimation of rerupture rates. In population surveys, exposure data are useful because they represent the injury risk according to activity. For example, in our data set, an equal incidence of ACL ruptures occurred during men's football competition and practice; however, based on exposure, there was a significantly higher rupture rate during competition than practice because football players have more practice scenarios than game scenarios during their seasons.

The use of the NCAA ISP database has the inherent limitation of a voluntary, trainer-driven reporting system with no confirmation of data. Last, the ISP data set did not report all injury-specific characteristics such as team-specific attributes (eg, participation in ACL injury prevention programs). If prevention programs were introduced during the study period, they could have influenced injury rates.

CONCLUSION

Our results indicate that the rate of recurrent ACL ruptures for many sports, including men's football, women's gymnastics, and women's field hockey, remained high. Women's soccer players had a significantly higher rate of recurrent ACL ruptures compared with men's soccer players. These data can help identify athletes who are most at risk of recurrent ACL ruptures after ACL reconstruction and who may benefit from injury prevention programs. Further studies are needed to identify the causes of and modifiable risk factors for a recurrent ACL rupture.

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