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Am J Sports Med 2006 34: 899
DOI: 10.1177/0363546505285582

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Comparing the Incidence of Anterior Cruciate Ligament Injury in Collegiate Lacrosse, Soccer, and Basketball Players

Implications for Anterior Cruciate Ligament Mechanism and Prevention

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Background: Female college basketball and soccer athletes have higher rates of anterior cruciate ligament injury than do their male counterparts. Rates of anterior cruciate ligament injuries for women and men in collegiate lacrosse have not been examined. Understanding anterior cruciate ligament injury patterns in lacrosse, a full-contact sport for men and noncontact sport for women, could further injury prevention efforts.

Hypotheses: Female anterior cruciate ligament injury rates will decrease over time owing to longer participation in sports. Lacrosse anterior cruciate ligament injury rates will be lower than rates in basketball and soccer possibly owing to beneficial biomechanics of carrying a lacrosse stick.

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

Methods: Data from the National Collegiate Athletic Association Injury Surveillance System were analyzed to compare men's and women's anterior cruciate ligament injuries in basketball, lacrosse, and soccer over 15 years.

Results: Anterior cruciate ligament injury rates in women's basketball and soccer were 0.28 and 0.32 injuries per 1000 athlete exposures, respectively, and did not decline over the study period. In men's basketball, injury rate fluctuated between 0.03 and 0.13 athlete exposures. Rates of anterior cruciate ligament injury did not significantly change in men's soccer over the study period. The rate of anterior cruciate ligament injury in men's lacrosse (0.17 athlete exposures, $P < .05$) was significantly higher than in men's basketball (0.08 athlete exposures) and soccer (0.12 athlete exposures). Injury rate in women's lacrosse (0.18 athlete exposures, $P < .05$) was significantly lower than in women's basketball and soccer.

Conclusion: There was no discernable change in rate of anterior cruciate ligament injury in men or women during the study period. Men's lacrosse is a high-risk sport for anterior cruciate ligament injury. Unlike basketball and soccer, the rates of anterior cruciate ligament injury are essentially the same in men's and women's lacrosse. The level of allowed contact in pivoting sports may be a factor in determining sport-specific anterior cruciate ligament risk.

Keywords: anterior cruciate ligament (ACL) injury; lacrosse; collegiate; women

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The views expressed herein are those of the authors and should not be construed as official policy of the Department of the Air Force or the Department of Defense.

No potential conflict of interest declared. No author institution has received any financial benefit.

Anterior cruciate ligament injuries are common in collegiate sports. Based on data from a sampling of collegiate men's soccer teams, there were an estimated 69 ACL injuries nationwide in a single season.¹¹ Tears of the ACL can be devastating injuries because many athletes do not return to their preinjury levels of participation, despite aggressive rehabilitation. There are also long-term sequelae associated with these injuries, such as arthritis and other health risks that occur from the resulting decrease in physical activity. Previously published studies have shown that ACL injuries

are owing primarily to noncontact mechanisms.^{4-8,11,13} However, it may be more correct to view many ACL injuries as minimal-contact injuries: injuries sustained while attempting to avoid contact or while being distracted by potential contact with another player. High-risk mechanisms for noncontact or minimal-contact ACL injuries include cutting, jumping, sudden deceleration, and checking (body contact with another player).^{4,6} Athletes involved in basketball, soccer, and lacrosse are constantly exposed to these potentially damaging forces as they perform countless repetitions of these maneuvers in both practice and game situations.

Despite similar maneuvers and playing conditions in many men's and women's sports, women often have much higher rates of ACL injury than do their male counterparts.^{5,7,13} In an article published in 1995, Arendt and Dick³ tested the hypothesis that female athletes are more susceptible to ACL injury than are male athletes in the sports of basketball and soccer. Using data from the National Collegiate Athletic Association (NCAA) Injury Surveillance System (ISS),¹¹ they found that female athletes had an increased incidence of ACL injuries compared with male athletes over a period of 5 years in the sports of soccer and basketball. This classic study heightened awareness of ACL injury in female athletes and has spawned many other studies examining gender differences in specific rates of injury. In the 10 years since the publication of this landmark study, participation in women's sports has continued to evolve with increased numbers of participants and earlier age of participation in organized sports.^{2,9} In fact, according to the NCAA, there were more colleges sponsoring women's soccer, basketball, and lacrosse teams than corresponding men's teams in 2003.¹⁰ In April 2005, Agel et al¹ published a follow-up study on the rate of ACL injury in men's and women's soccer and basketball over a 13-year period, observing similar rates in basketball but slightly higher rates of injury in women's soccer.

The purpose of this study was (1) to update the rates of ACL injury in matched men's and women's sports (soccer and basketball) and (2) to compare these ACL injury rates to those in men's and women's lacrosse. We hypothesized that a lower rate of ACL injuries in female soccer and basketball athletes would be evident over the past 10 years if any of the excess ACL risk in women athletes was owing to shorter length of participation in organized sport and possibly lower fitness level. We also hypothesized that the risk of ACL injury would be lower in both men's and women's lacrosse when compared with basketball and soccer. We based this hypothesis on the perception in our clinical practice that ACL injuries in lacrosse players are relatively rare, possibly owing to the increased balance gained by carrying the stick (crosse). We were further motivated by the increasing popularity of lacrosse and a desire to better understand the differences and trends in injury patterns between men's and women's lacrosse.

MATERIALS AND METHODS

Data were collected using the NCAA ISS. The NCAA began collecting data using the ISS in 1982 to provide injury

trends in intercollegiate sports. The data are taken from a sample of NCAA colleges each year. In 1989, an additional question was added to the ISS to indicate which structure in the knee was injured. Therefore, data were used from 1989 through the most current year available, 2004. However, data from the 1996-1997 academic year are not available through the NCAA because of internal problems with the data set that year. It was not until 2003 that the additional information of mechanism of ACL injury (contact vs noncontact) was documented. Therefore, these data could not be included in our analysis.

The NCAA ISS collects data from a sampling of collegiate institutions nationwide. The selections are random but must have a minimum of 10% representation of each NCAA division (I, II, and III) and region (East, South, Midwest, and West). This sampling scheme ensures a true cross section of NCAA institutions, which can be used to express injury rates representative of the total population of NCAA institutions sponsoring a particular sport.

Injury and exposure data are recorded by certified and student athletic trainers from the participating institutions. Information is collected from the first official day of preseason practice to the final tournament contest. A reportable injury in the ISS is defined as "one that occurs as a result of participation in an organized intercollegiate game or practice, requires medical attention by a team athletic trainer or physician, and results in restriction of the student-athlete's participation for one or more days beyond the day of injury."¹¹ The unit of risk in the ISS is the athlete exposure. An athlete exposure is defined as 1 athlete participating in 1 practice or game in which he or she is exposed to the possibility of athletic injury. Injury rate in the ISS is expressed as the number of injuries per 1000 athlete exposures.

Our study examined sex-specific and game-specific ACL injuries during a 15-year period, from 1989 to 2004, excluding the 1996-1997 academic year, in basketball, soccer, and lacrosse. The first 2 sports were used as standards with which to compare lacrosse, as the former 2 sports have been extensively studied in the past.^{1,3}

In soccer, a total of 1097 men's teams (mean, 78 per year) and 1034 women's teams (mean, 74 per year) provided data to the ISS. In basketball, a total of 1488 men's teams (mean, 106 per year) and 1530 women's teams (mean, 109 per year) provided data to the ISS. Finally, in lacrosse, a total of 453 men's teams (mean, 32 per year) and 552 women's teams (mean, 39 per year) provided data to the ISS. For each sport, tables were made organizing athlete exposures, those resulting in injury and those not resulting in injury, by sex. The tables were then analyzed using the standard χ^2 technique, and injury rates were noted to be lower than expected, equal to expected, or higher than expected for each sex. In addition, the injury rates in lacrosse were compared, by sex, to the injury rates in basketball and soccer and were analyzed using the χ^2 technique. Statistical significance was noted at the $P < .05$ level.

RESULTS

All rates are given per 1000 athlete exposures. The results for the 3 sports are summarized in the tables.

TABLE 1
Anterior Cruciate Ligament Injury Rate in National Collegiate Athletic Association Soccer, 1989-2004

	1989-1994 ^a		1994-2004		1989-2004	
	Male	Female	Male	Female	Male	Female
Athlete exposures ^b	626 223	308 748	1 148 918	986 321	1 772 029	1 441 546
ACL injuries (percentage of total injuries)	81 (1.6)	97 (3.8)	131 (1.5)	317 (4.0)	212 (1.6)	457 (3.9)
ACL injury rate ^c (<i>P</i> value)	0.13	0.31 (.00)	0.11	0.32 (<.05)	0.12	0.32 (<.05)

^aData as reported by Arendt and Dick.³

^bOne athlete exposure is defined as 1 athlete in 1 practice or game.

^cRate expressed as per 1000 athlete exposures.

TABLE 2
Anterior Cruciate Ligament Injury Rate in National Collegiate Athletic Association Basketball, 1989-2004

	1989-1994 ^a		1994-2004		1989-2004	
	Male	Female	Male	Female	Male	Female
Athlete exposures ^b	736 076	639 898	1 328 804	1 142 639	2 269 927	1 950 672
ACL injuries (percentage of total injuries)	49 (1.2)	189 (5.7)	108 (1.5)	321 (5.1)	175 (1.4)	551 (5.2)
ACL injury rate ^c (<i>P</i> value)	0.07	0.29 (.00)	0.08	0.28 (<.05)	0.08	0.28 (<.05)

^aData as reported by Arendt and Dick.³

^bOne athlete exposure is defined as 1 athlete in 1 practice or game.

^cRate expressed as per 1000 athlete exposures.

Soccer

The ACL injury rates reported by Arendt and Dick³ are similar to the rates we observed over the past 10 years and over the entire 15-year period. Women have higher rates than do men. These results are listed in Table 1.

Basketball

We also observed similar rates of ACL injury in basketball players over the past 10 years as those reported by Arendt and Dick.³ These results are listed in Table 2, showing that women have higher rates than do men.

Lacrosse

We found no significant difference between the ACL injury rates of men and women during this 15-year period, as seen in Table 3 and Figure 1.

However, when compared with soccer and basketball, significant differences were apparent. In the men's game, there is a statistically significantly higher rate of ACL injury in lacrosse than in both basketball and soccer (see Table 4 and Figure 2). However, in the women's game, there is a statistically significantly lower rate of ACL injury in lacrosse than in the other 2 sports (see Table 5 and Figure 3).

TABLE 3
Anterior Cruciate Ligament Injury Rates in National Collegiate Athletic Association Lacrosse, 1989-2004

	Lacrosse	
	Men	Women
Athlete exposures ^a	984 292	799 611
ACL injuries (percentage of total injuries)	169 (3.3)	146 (4.2)
ACL injury rate ^b (<i>P</i> value)	0.17	0.18 (.59)

^aOne athlete exposure is defined as 1 athlete in 1 practice or game.

^bRate expressed as per 1000 athlete exposures.

DISCUSSION

This study supports the previously reported data of Arendt and Dick³ that showed higher rates of ACL injury in female soccer and basketball players compared with male players. The study by Agel et al¹ also revealed similar data: the risk of ACL injury in women is higher than in men in basketball and soccer. There has been little overall change in the rate of ACL injuries in these sports during the time studied (see Tables 1 and 2). The rate of soccer ACL injuries over this

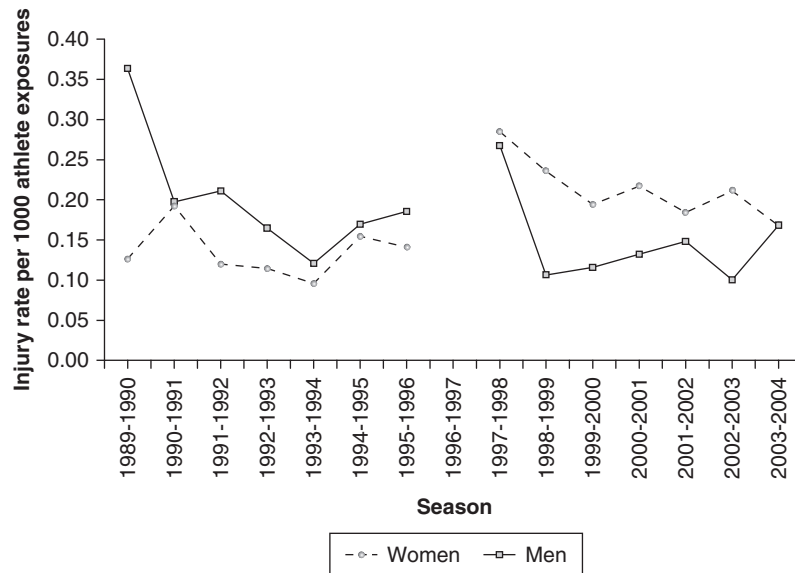


Figure 1. Anterior cruciate ligament injuries in male and female lacrosse players.

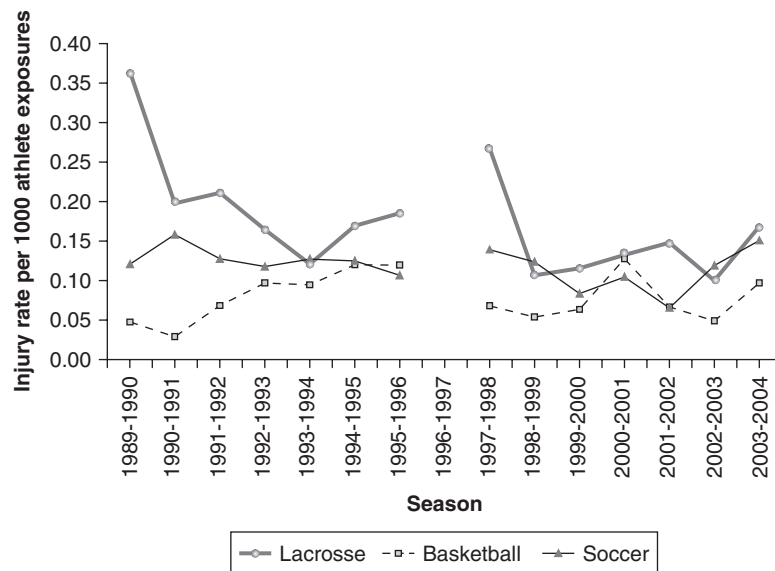


Figure 2. Anterior cruciate ligament injuries in men's lacrosse, basketball, and soccer.

15-year period is almost 3 times higher in women than in men (incidence rate ratio, 2.73; 95% confidence interval, 2.29-3.25). In basketball, the rate of injuries in women is almost 4 times higher than in men (incidence rate ratio, 3.77; 95% confidence interval, 3.14-4.53).

Previous authors have suggested that female ACL injury may occur at a higher rate than in male athletes partly because of the fact that female athletes have been playing organized sports for a shorter period of time or are less fit or had less training than did their male counterparts.^{3,8} Current evidence has documented earlier, more organized participation in sports by young female athletes and continuing trends toward increased levels of fitness among female

athletes.^{2,9} However, despite these documented changes in the experience and fitness of female athletes over the past 10 years, our study did not demonstrate any downward trend in the incidence of female ACL injury. In fact, there appears to be a slight upward trend in women's soccer in recent years, whereas a definite trend cannot be identified in women's basketball (see Figure 3). Therefore, the increased fitness and sports experience of today's female athletes have not yet translated into any demonstrable decrease in their risk for ACL injury.

In women's sports, the rate of ACL injury in lacrosse is consistently lower than in soccer and, with few exceptions, lower than in basketball (see Figure 3). The rate of injury in

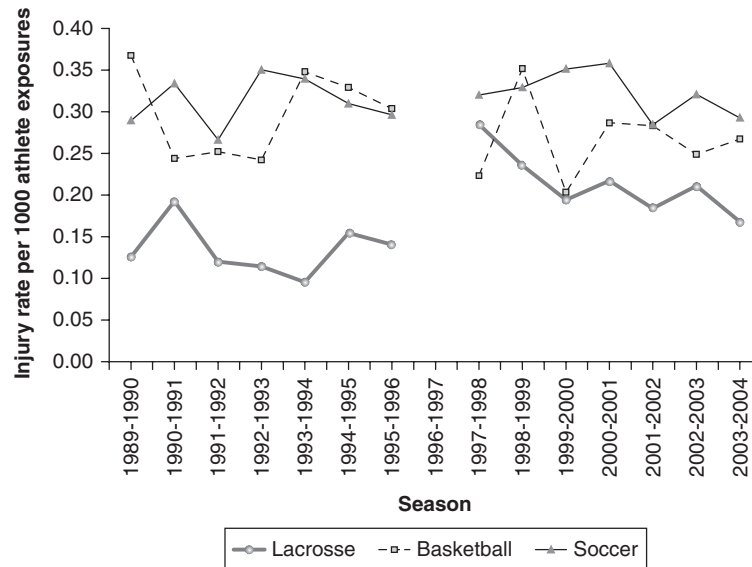


Figure 3. Anterior cruciate ligament injuries in women’s lacrosse, basketball, and soccer.

TABLE 4

Anterior Cruciate Ligament Injury in Men’s Lacrosse, Soccer, and Basketball, 1989-2004

	Lacrosse	Soccer	Basketball
Athlete exposures ^a	984 292	1 772 029	2 269 927
ACL injuries (percentage of total injuries)	169 (3.3)	212 (1.6)	175 (1.4)
ACL injury rate ^b (P value compared with lacrosse)	0.17	0.12 (<.05)	0.08 (<.05)

^aOne athlete exposure is defined as 1 athlete in 1 practice or game.
^bRate expressed as per 1000 athlete exposures.

TABLE 5

Anterior Cruciate Ligament Injury in Women’s Lacrosse, Soccer, and Basketball, 1989-2004

	Lacrosse	Soccer	Basketball
Athlete exposures ^a	799 611	1 441 546	1 950 672
ACL injuries (percentage of total injuries)	146 (4.2)	457 (3.9)	551 (5.2)
ACL injury rate ^b (P value compared with lacrosse)	0.18	0.32 (<.05)	0.28 (<.05)

^aOne athlete exposure is defined as 1 athlete in 1 practice or game.
^bRate expressed as per 1000 athlete exposures.

lacrosse is nearly half of that in soccer (incidence rate ratio, 0.58; 95% confidence interval, 0.47-0.71). This finding may be explained by the fact that women’s soccer involves more contact than does women’s lacrosse. Incidental trauma or

minimal trauma, which may lead to an awkward landing position or a disturbance in the neuromuscular patterns that protect the knee, may be key factors in ACL injuries.^{4,6} However, without information on the mechanism of how the injuries occurred, this remains a hypothesis.¹² There is what appears to be an abrupt increase in the rate of ACL injury in women’s lacrosse between the 1995-1996 and 1997-1998 seasons. Without the data from the 1996-1997 season (unavailable from the NCAA), it is difficult to determine the actual trend. There is no readily identifiable extrinsic explanation for this apparently abrupt increase in ACL injury, based on the history of women’s lacrosse or in adjustment to the rules of play.¹⁴

In contrast to women’s sports, the rate of ACL injury in men’s lacrosse is higher than in soccer and basketball (see Figure 2). The rate of injury is twice as high in men’s lacrosse compared with basketball (incidence ratio rate, 2.28; 95% confidence interval, 1.82-2.87). Compared with soccer, there is a 1.5 times higher rate of injury in lacrosse (incidence ratio rate, 1.47; 95% confidence interval, 1.18-1.82). Again, increasing levels of ACL injuries parallel increased levels of contact, as men’s lacrosse involves more contact than does men’s soccer, which has more contact than does men’s basketball. There is some disparity in the rate of male ACL injury seen between the 1995-1996 and 1997-1998 seasons, but this does not approach the near doubling in ACL rate observed in the women’s game over this same time. The last 5 years of data available may represent the beginning of a downward trend in the rate of ACL injury in men’s lacrosse, but more data are needed to make that judgment.

Direct comparisons between men’s and women’s lacrosse are problematic because the rules of play are fundamentally different. Over a 15-year period (see Figure 1), men’s lacrosse, a contact sport, displayed a similar rate of ACL injuries as its noncontact counterpart, women’s lacrosse (incidence rate ratio, 1.07; 95% confidence interval, 0.84-1.36). However, it is

interesting to note that before the 1996-1997 gap, the rate of ACL injury in women's lacrosse was consistently less than or equal to the corresponding male lacrosse rate. After 1997-1998, the ACL injury rate was consistently higher in women's lacrosse than in men's lacrosse. This apparent change in women's ACL injury in lacrosse is also seen in comparison with women's basketball and soccer (see Figure 3). After the 1997-1998 season, the rate of ACL injury in female lacrosse players was more similar to that seen in basketball and soccer. This apparent increase in ACL injury rate in female players may represent increased pace or physicality of play in lacrosse, although no overt rule change or other contributing factor has been identified.¹⁴

Finally, this study definitively demonstrated a very high rate of ACL injury among men's lacrosse players. The risk of ACL injury in men's lacrosse was consistently higher than for basketball or soccer—a fact that was previously unappreciated. Our data did not distinguish minimal-contact ACL injuries from those caused by direct trauma. However, the rules and play style of men's lacrosse suggest that indirect mechanisms would account for the overwhelming majority of these injuries. Although our study was not designed to examine the mechanism for ACL injury in lacrosse or any other sport, it appears that carrying the lacrosse stick (crosse) may not provide significant protection against ACL injury in men's lacrosse. Alternatively, it could be that any protective biomechanics gleaned from crosse carrying are more than offset by the nature of the game itself. It does appear that the level of contact in sports is associated with the risk for ACL injury.

The biomechanical questions surrounding ACL injury and the addition of men's lacrosse to the group of "high-risk" ACL sports further highlight the compelling need for more research into the prevention of ACL injury. The key to injury prevention is an accurate understanding of biomechanical risk factors, followed by prospective identification and demonstrable changing of those factors presumed to be modifiable, culminating in proven decreases in long-term ACL injury rates. Further study of ACL injury patterns and prospective identification of specific risk factors are warranted and essential to the goal of decreasing injury among an ever-growing group of athletes.

CONCLUSION

1. Men's lacrosse is a high-risk sport for ACL injuries.
2. There was no change in the incidence of ACL injuries in female basketball and soccer players during the study period.

3. Despite the increased baseline risk of ACL tear in female athletes in other sports, female lacrosse players have similar rates of ACL injury to those of their male counterparts. This finding may be owing to the differences in the amount of allowable contact in women's and men's lacrosse. The level of allowable contact in cutting sports seems to correlate with the risk of ACL injury.

ACKNOWLEDGMENT

Funding for this project was provided through a research grant from the Uniformed Services University of the Health Sciences. Statistical consultation and review were provided by Cara Olsen, PhD, Biostatistics Consulting Center, Uniformed Services University, Bethesda, Maryland.

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