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Am. J. Sports Med. 2003; 31; 601

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Intraarticular Injuries Associated with Anterior Cruciate Ligament Tear: Findings at Ligament Reconstruction in High School and Recreational Athletes

An Analysis of Sex-Based Differences

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Background: Despite research on the increased risk of anterior cruciate ligament tears in female athletes, few studies have addressed sex differences in the incidence of associated intraarticular injuries.

Hypothesis: When patients are stratified by sport and competition level, no sex differences exist in either the mechanism of injury or pattern of intraarticular injuries observed at anterior cruciate ligament reconstruction.

Study Design: Prospective cohort study.

Methods: Two hundred twenty-one athletes undergoing anterior cruciate ligament reconstruction met our inclusion criteria of anterior cruciate ligament tear as a singular event without reinjury or history of prior injury or surgery in either knee. Data were collected on competition level (high school, amateur), sport (basketball, soccer, skiing), mechanism of injury, articular cartilage injuries, and meniscal tears. Data were statistically analyzed by sex with the chi-square test and Student's *t*-test.

Results: High school athletes had no significant sex differences in mechanism of injury. Female soccer athletes had fewer medial meniscal tears than did male athletes, and female basketball players had fewer medial femoral condyle injuries. At the amateur level, female basketball players had more contact injuries, an earlier onset of swelling, and fewer lateral meniscal tears than did male players.

Conclusion: At the high school level, male and female athletes shared a common mechanism of injury, and yet the female athletes had fewer intraarticular injuries in basketball and soccer. If such intraarticular injuries prove to be a significant risk factor for poor long-term outcome, women may enjoy a better prognosis after reconstruction.

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Despite general acknowledgment that overall injury patterns in athletics are sport-specific,³¹ a growing body of research suggests that female athletes have an increased tendency toward knee injuries in general^{9,38} and are two to six times more likely to suffer ACL tears than their male counterparts across a variety of sports and activities.^{2,6,15,17,23,26,30} Given that for most sports the knee is the most common site of injury requiring surgery,^{11,21,26} an understanding of this sex difference becomes impor-

tant for its value in injury prevention and treatment. This is particularly true if the injuries themselves are actually different between male and female athletes, because this would imply both sex-specific mechanisms of injury and potential sex-based differences in long-term outcome.^{5,14}

The association between ACL tear and other intraarticular damage is well established,³⁶ and it is believed that such injuries will influence long-term outcome. Despite a lack of long-term follow-up in patients with these injuries, several studies suggest that progressive osteoarthritis occurs after articular cartilage damage or meniscal injury or repair.^{7,10,19,27,29,35,37} To date, however, there has been no definitive study on sex differences in the associated intraarticular injuries found at the time of ACL recon-

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No author or related institution has received any financial benefit from research in this study.

struction. Furthermore, no studies have effectively evaluated sex differences in mechanism of injury by sport and competition level in high school.

In the only study specifically addressing these issues, Arendt and Dick² retrospectively reported no significant sex differences in associated intraarticular injuries among collegiate athletes except for an increase in meniscal tears among women. The authors attributed this finding to the known association between ACL injury and meniscal damage. Regarding injury mechanism, the authors reported more noncontact ACL tears among women. Unfortunately, these observations are weakened by the lack of any systematic examination of intraarticular lesions and by a failure to account for any prior knee injury or surgery.

In the published research on ACL tears, there has been no prospective examination of sex-specific differences in the observed intraarticular lesions associated with ACL tears. Nor has there been any prospective examination of the mechanism of injury by controlling for confounding variables like sport, skill level, and prior knee injury or surgery. The purpose of this study was to evaluate the question of sex differences in patients with ACL tears at the time of reconstruction by prospectively documenting the intraarticular lesions and mechanism of injury in a prospective database of patients undergoing ACL reconstruction. The patients studied were in a population wherein the intraoperative findings were a result of ACL tear that occurred as a singular event, without history of prior injury, surgery, or reinjury between diagnosis and reconstruction.

MATERIALS AND METHODS

Subject injury information was drawn from a prospective database designed in 1990 to document factors related to mechanism and etiologic basis of injury and associated intraarticular lesions in patients undergoing ACL reconstruction. The parameters defining this data collection were presented and published when the database was begun.³⁶

We evaluated a total of 1193 consecutive patients with a confirmed grade III ACL injury who underwent ACL reconstruction between 1990 and 2000 at Vanderbilt University and The Cleveland Clinic Foundation. Preoperative questionnaires were designed to collect basic demographic information (age, sex, weight, height), as well as the patient's sport and competition level (high school versus amateur or recreational), injury mechanism (injury side, contact or noncontact injury, whether jumping was involved, onset of swelling, whether there was a perceived "pop," and return to play), and a detailed surgical and injury history regarding both knees. A preoperative examination under anesthesia of both knees was performed and documented by one of three surgeons (KPS, RDP, JTA). Arthroscopic findings of associated meniscal (lateral, medial), ligament (ACL, PCL, medial collateral ligament, lateral collateral ligament), and articular cartilage injuries (site, size, chondromalacia grade) were recorded intraoperatively at the time of ACL reconstruction. To be included, patients had to have an acute grade III ACL tear (verified pre- and intraoperatively). Patients were excluded if they reported reinjury or prior surgery in either

knee. A component of the questionnaire required that patients report this surgical and injury history, excluding the recent ACL tear for which they sought reconstruction. Any evidence of prior surgery was also verified intraoperatively and, if found, these patients were excluded. Of the 1193 patients, 571 patients met these criteria.

The 571 patients were injured during participation in the following sports: football (98), volleyball (14), skiing (56), soccer (56), basketball (161), baseball/softball (26), gymnastics (6), and other sports (88). A total of 66 patients were injured during activities other than sports or by other means. Of the 571 patients, 221 patients met inclusion criteria with sufficient sample size in sports in which both men and women participate. These patients were then further stratified by sport and competition level, with the distribution as follows: high school soccer (19), amateur/recreational soccer (22), amateur/recreational skiing (34), high school basketball (80), and amateur/recreational basketball (66). The distribution by sport of the 350 excluded patients was as follows: football (98); volleyball (14); baseball (26); gymnastics (6); other sports (88); no sports (66); college to professional level skiing, soccer, basketball (20); and undetermined level of a particular sport (32). All inclusion and exclusion criteria were established before any analysis.

Demographic information, reported mechanisms of injury, and associated intraarticular findings were compared between men and women within each of the included groups. Data were statistically evaluated by using chi-square analysis for categorical variables and the Student's *t*-test for continuous variables; the confidence interval was 95%.

RESULTS

Demographic Data

A comparable number of male (97) and female (124) athletes were included in the database. Female athletes in both the high school and amateur basketball groups were significantly younger than men were; there was no significant age difference by sex within any other group. As expected, female athletes were lighter (weight) and smaller (height) in all categories. In our population of patients undergoing ACL reconstruction, female athletes outnumbered male athletes in high school basketball (9 to 1) and soccer (1.7 to 1), whereas there were more male participants in amateur basketball (5 to 1), soccer (2.7 to 1), and skiing (1.6 to 1).

Intraarticular Injury

The distribution of intraarticular injuries by level of competition (high school versus amateur) and sport is shown in Tables 1 and 2. At the high school level, women were noted at the time of surgery to have significantly fewer medial meniscal tears in soccer ($P = 0.02$). Also, a trend was seen for female high school athletes to have fewer complete lateral meniscal tears in basketball ($P = 0.07$). With respect to articular cartilage injury, which was defined as visible chondral lesions, including fracture and any chondromalacia (grades I to IV), female basketball

TABLE 1
Intraarticular Injuries and Mechanism of Injury in Male and Female High School Athletes

	Basketball players (%)			Soccer players (%)		
	Male	Female	<i>P</i>	Male	Female	<i>P</i>
Number	8	72	—	7	12	—
Noncontact	62	71	NS ^a	57	75	NS
Jumping	88	60	NS	43	25	NS
Pop	88	79	NS	71	75	NS
Meniscal tears						
Medial - all	25	42	NS	86	25	≤0.02
Medial - complete only	25	32	NS	57	17	NS
Lateral - all	75	60	NS	14	50	NS
Lateral - complete only	75	39	0.07	14	33	NS
Articular cartilage injury						
Lateral femoral condyle	25	36	NS	43	50	NS
Medial femoral condyle	50	17	<0.05	14	25	NS

^a Not significant.

TABLE 2
Intraarticular Injuries and Mechanism of Injury in Male and Female Amateur Athletes

	Basketball players (%)			Soccer players (%)			Skiers (%)		
	Male	Female	<i>P</i>	Male	Female	<i>P</i>	Male	Female	<i>P</i>
Number	53	13	—	16	6	—	13	21	—
Noncontact	77	38	≤0.016	56	66	NS	100	86	NS
Jumping	65	46	NS	31	0	NS	15	14	NS
Pop	83	92	NS	50	50	NS	54	62	NS
Meniscal tears									
Medial - all	53	31	NS	31	33	NS	46	24	NS
Medial - complete only	45	31	NS	25	33	NS	15	14	NS
Lateral - all	69	38	0.056	63	67	NS	54	67	NS
Lateral - complete only	58	15	≤0.01	25	50	NS	38	19	NS
Articular cartilage injury									
Lateral femoral condyle	42	23	NS	31	17	NS	15	24	NS
Medial femoral condyle	37	23	NS	0	33	0.065	8	5	NS

players were noted to have significantly fewer medial femoral condyle injuries than did male players ($P = 0.05$). No significant differences were observed in other articular surfaces or injuries to the collateral ligaments.

At the amateur level, female basketball players were noted to have significantly fewer complete lateral meniscal tears than male basketball players ($P = 0.01$). A trend toward fewer total (partial and complete) lateral meniscal tears ($P = 0.056$) was also noted in this group. There was also a trend toward more medial femoral condyle injuries in female soccer players compared with male soccer players ($P = 0.065$) and an increased frequency of medial collateral ligament sprains in female skiers versus male skiers ($P = 0.08$). No other significant sex differences in intraarticular or collateral injuries were observed.

Mechanism of Injury

At the high school level, no significant sex differences in mechanism of injury were observed. Most commonly, injuries involved a noncontact mechanism (57% to 75% of injuries), with 60% to 88% of basketball players and 25% to 43% of the soccer players reporting that jumping was involved. There were no differences between sexes in reports of a pop (71% to 88%), return to play, side, or onset of swelling.

At the amateur level, female basketball players suffered significantly more contact injuries than male players ($P \leq 0.016$) and reported an earlier onset of swelling ($P = 0.027$). As with high school athletes, amateur basketball players of both sexes reported that jumping was a common mechanism (46% to 65%) of injury, with almost all athletes reporting a pop. There were no significant differences in mechanism of injury by sex for amateur soccer or amateur skiing groups. Only in the amateur skiing group was there a trend toward increased frequency of medial collateral ligament injuries in women compared with men ($P = 0.08$).

DISCUSSION

A substantial body of research now suggests that women are more prone to ACL injury than are men.^{2,6,15,17,23,26,30} The greatest increase in risk has been shown among basketball and soccer players, with women sustaining a two- to five-fold greater risk than their male counterparts.^{2,6,23,26} Nonetheless, a significantly increased risk for women has been demonstrated across multiple sports and activities,^{15,17,30} with implication of numerous sex differences from skill level and muscle strength/recruitment to limb alignment,²⁸ intercondylar notch dimensions, and joint laxity.² Given the frequency with which

these serious injuries occur in sports, significant attention has turned in recent years toward elucidating these and other factors in an attempt to explain this sex disparity. Despite the potential effect of associated intraarticular injuries on future outcome, there has been little research on sex differences in articular cartilage injuries occurring with ACL tears, and no research has been performed taking into consideration sport and competition level.

The association of intraarticular lesions with ACL tears, irrespective of sex, is well known^{1,8,32,33,36} and has been documented arthroscopically in as many as 70% to 80% of cases in some prospective studies.^{8,33,36} The same investigators have found associated meniscal tears in 60% to 70% of knees with grade III ACL injuries,^{8,33,36} with lateral meniscal tears reported in 56% (30 of 54) of patients and medial meniscal tears in 37% (20 of 54).³⁶ In a study of 54 patients who underwent ACL reconstruction, Spindler et al.³⁶ found articular cartilage lesions associated with ACL tears in 46%, with arthroscopy revealing visible damage of the lateral and medial femoral condyles (injured in 28% and 20% of patients, respectively), as well as the lateral and medial tibial plateaus (injured in 13% and 6% of patients, respectively). Grades I and II collateral ligament injuries have been documented in 5% to 24% of knees with ACL tears.^{33,36} In our study, the frequency of associated meniscal tears, articular cartilage damage, and collateral ligament injuries was consistent with that of these reports.

This is the first study to report not only sex differences in intraarticular injuries documented at arthroscopy for ACL reconstruction, but also to account for sport and level of competition. Although Nielson and Yde³² and Arendt and Dick² evaluated sex difference in intraarticular injuries, they could not control for whether the ACL injury was a singular event, type of sport involved, or level of competition. In this study, we found that female high school athletes had fewer meniscal tears (soccer) and a reduced number of intraarticular injuries to the medial femoral condyle in basketball. If these injuries are risk factors for the long-term development of arthritis, male athletes may be predisposed to poorer function. Long-term prospective studies are underway to address this issue.

The reason sex differences exist at the high school level is not clear. Noncontact injury^{13,25,34,36} and jumping,³⁶ which were the major injury mechanisms, were not different between sexes. Nor was the incidence of swelling different between sexes. Thus, it may be that more subtle sex-specific differences in injury mechanism are to blame. The finding of fewer medial compartment injuries (medial femoral condyle, medial meniscus) among female athletes does suggest some type of difference in mechanism. We hypothesize that this sex-specific pattern of intraarticular injury reflects the influence of greater varus alignment and greater generation of forces in the significantly heavier and taller male athletes. Anatomic differences in force distribution,³ differential articular cartilage volumes,^{12,22} and neuromuscular differences in quadriceps muscle contraction^{16,20,28} or hamstring muscle firing^{4,20,28} may also play a role but require further prospective evaluation with stratification by sport and competi-

tion level. It is also possible that sex-specific differences at the tissue level are involved. The observed injury patterns might partly be explained by a lesser degree of ACL resiliency in women, leading to ACL failure at smaller forces and thus less associated joint damage. Alternatively, the patterns could be partly due to less resilient articular cartilage and meniscal tissue in men. Further investigation into these potential sex differences is necessary before such tissue-level influences can be evaluated.

At the amateur level, it is more difficult to make sex comparisons. Although a significant difference in intraarticular lesions among high school athletes occurred in the female basketball players (fewer lateral meniscal tears in women), the greater incidence of contact injuries among these female athletes represents a significant confounding variable. A host of different contact blows—perhaps providing preferentially varus loads—may explain the reduced incidence of lateral meniscal tears among these female athletes. Nonetheless, given the complexity introduced by these differences in mechanism, in addition to more significant variations in skill level, wider gaps in ages and weights, sex comparisons among the amateur athletes can only be speculative.

Blunt trauma to articular cartilage has been shown experimentally and clinically to cause pathologic alterations in articular cartilage structure. Various investigators have arthroscopically documented injuries correlated with bone bruises seen on MRI,³⁶ confirmed initial histologic and biochemical findings associated with blunt trauma,¹⁰ and arthroscopically documented that degeneration follows blunt trauma in experimental models.^{7,37} Even in the best-case scenario, subtle abnormal joint laxity after ACL reconstruction leads to increased stress on the meniscus or leads to articular cartilage injuries, potentially resulting in future degeneration.^{7,19,27,29,35} Thus, regardless of the cause, the lower number of associated injuries observed in the female athletes in this study could lead to fewer long-term knee problems after their ACL reconstruction, as compared with their male counterparts. The database we established in 1991 was designed to prospectively collect information on mechanism of injury, provide an assessment of prior injuries and reinjuries, document sport and competition level, and record intraoperative data. This database is the foundation for the Multicenter Orthopaedic Outcomes Network (MOON) established in 2001. Future analysis for outcome assessment by validated questionnaires will determine whether different patterns of injuries observed between the sexes is significant in the long term.

Further research on the role of skill level¹⁸ and more specific mechanisms of injury, such as the sidestep maneuver,²⁴ need to be prospectively evaluated. Documentation of intraarticular injuries and outcomes would provide potential ways to reduce the occurrence of ACL tears.

This investigation has several limitations. First, by pooling patients from multiple schools and teams, the study population, although stratified by sport and competition level, is complicated by variations in different practice regimens, conditioning programs, and competition schedules. Second, some subjects were not evaluated in-

traoperatively until 3 months after injury. Despite specific questioning of all subjects regarding reinjury, this created the potential for additional unreported injuries. Third, as expected, female athletes were both lighter and smaller than their male counterparts and the role this might play in patterns observed is unknown. Because there is no universally agreed on way to control for size and weight differences, further research is needed in this area. Fourth, the intraarticular injuries and mechanisms reported here were only for patients undergoing ACL reconstruction and do not represent all ACL tears. Nonetheless, among the high school population of athletes this represents nearly all ACL tears, because the majority of these patients undergo reconstruction. Fifth, despite our screening by history, subtle subluxations of the injured knee after the ACL tear could potentially have altered the pattern of intraarticular injuries. Despite this, we believe our study has controlled for reinjury, prior surgery, level of competition, and size and weight better than previous investigations.

CONCLUSION

Female high school athletes were observed to have significantly fewer intraarticular injuries in basketball (decreased medial femoral condyle injuries) and soccer (decreased medial meniscal tears), with no major differences in injury mechanism. We hypothesize that this sex difference in pattern of injury is partly the result of generally greater varus alignment in men. The reduced frequency of injuries among these female athletes may result in their obtaining a better long-term functional outcome after ACL reconstruction. Among amateur athletes, the finding of fewer lateral meniscal tears in female basketball players is difficult to evaluate because of significant confounding variables, including major differences by sex in mechanism of injury and greater discrepancies of skill level, age, and weight.

ACKNOWLEDGMENTS

We thank Michelle Secic, MS, for her expertise in statistical analysis, Lynn Cain for editorial assistance, and John Bergfeld, MD, for guidance in database design.

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