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Epidemiology of Meniscal Injury Associated With ACL Tears in Young Athletes

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Abstract: The epidemiologic characteristics of concomitant meniscal tears that occur at the time of anterior cruciate ligament (ACL) injury have been variably reported. The purpose of this study was to assess the epidemiology of meniscal tears that occur in the ACL-injured knee of a young, athletic population at a single institution. We were unable to find a difference in meniscal tear incidence based on sex, mechanism of injury, sport, or time to surgery. In addition, we found that the cumulative incidence of isolated medial meniscal tears was significantly higher than the cumulative incidence of isolated lateral meniscal tears. Our prospective study design and ability to identify and follow all patients in our study population make this a unique study.

Meniscal injuries commonly occur in conjunction with anterior cruciate ligament (ACL) tears. Variability of the relative frequency of associated meniscal injuries, including sex differences and sport-specific injury patterns, have been demonstrated. The reported incidence of meniscal injury varies considerably, ranging from 16% to 82% in acute ACL tears and up to 96% in chronic ACL tears.[1-3] The lateral meniscus is injured more often in acute ACL tears, and the medial meniscus is more likely involved in chronic ACL tears.[1,4-7] Some authors have demonstrated unique sex- and sport-specific meniscal injury patterns associated with acute ACL tears.[8,9]

In the only prospective study evaluating intra-articular lesions associated with ACL tears, Piaseck et al[8] demonstrated that female high school soccer athletes were less likely to have a medial meniscal injury than their male counterparts. In addition, amateur female basketball players were more likely to sustain contact injuries and had fewer lateral meniscal tears. The authors attributed these findings to the ability to account for sport and level of competition in their study design.

In the study by Piaseck et al[8], patients were stratified to high school vs amateur or recreational athletes. To our knowledge, no prospective examination has been reported of associated meniscal injuries in high-level athletes with ACL tears that controls for confounding variables, such as sport, skill level, and mechanism of injury.

The purpose of the current study was to assess the epidemiology of meniscal tears that occur following an ACL injury in a young, athletic population at the United States Military Academy. Injuries were evaluated prospectively for 10 consecutive graduating classes at our institution between 1994 and 2003.

Materials and Methods

Institutional Review Board approval was obtained to prospectively follow 10 consecutive graduating classes of 10,419 cadets at the United States Military Academy, graduating in class years 1994 to 2003, to determine the incidence of ACL injuries in this cohort.[10] The methods for primary data collection and the physical activity requirements within this young, physically active cohort have been described previously.[10]

Diagnoses for new ACL injuries were based on history, physical examination, imaging, or arthroscopy.[10] All diagnoses were made by sports medicine fellowship-trained

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orthopedic surgeons at our institution. New patients with no prior history of ACL injury and complete ACL tears confirmed at the time of arthroscopy were included.

All participants in the current study received their health care through a closed health care system, which facilitated injury surveillance and permitted nearly complete follow-up in the study cohort. In addition, all students were required to participate in organized, rigorous physical activities that required an evaluation from a physician to be excused from. As a result, all new injuries were likely documented during the study period, with most patients' magnetic resonance images (MRIs) obtained close to the time of initial injury. All patients who sustained ACL injuries at our institution during the study period were included in the current study.

Because of the activity demands in the study population, almost all participants who injured their ACLs underwent subsequent arthroscopy and ACL reconstruction. Among the patients who underwent ACL reconstruction, concomitant intraoperative meniscal debridement or repair was documented. For the current study, a review of medical records, operative reports, and MRIs was completed to further inform the mechanism and nature of all meniscal injuries documented at the time of ACL reconstruction. Although all patients underwent MRI, the diagnosis of meniscal tear used for this study was the arthroscopic diagnosis.

One patient from our cohort elected not to undergo surgery, and the MRI data were used. Using these data, the overall incidence and characteristics of meniscal injury with concomitant ACL tears was determined. Demographic information, time to surgery, sex, sport played, mechanism of injury, and activity level were analyzed to determine their effect on the meniscal injury pattern. In addition to demographic and injury-specific information, the activity, level of sport at time of injury, and mechanism of injury (contact vs noncontact) were available for each patient based on the original database and study.

The different levels of sport included intercollegiate, club, intramural, and free time. Intercollegiate sports are those played at the NCAA Division I level. Intramural sports, which are mostly mixed sex, are similar to a high school level of play. Club sports are at an intermediate level between intercollegiate and intramural. Because students are required to maintain a high level of physical fitness and pass a physical fitness test twice annually, virtually all students remain active in their free time. As a result, free time was included as a category to account for several meniscal injuries. Participants who were participating in unorganized sports (eg, basketball during free time) were not stratified to that specific sport but rather were included in the free time category. Patients injured during summer military training were documented as military training for injury mechanism. For the purposes of this study, a contact mechanism was defined as an ACL injury resulting from contact to the body, and noncontact injuries were defined as an ACL injury resulting without contact with another person.[10]

Results

Our patient population included 10,419 cadets (9023 men, 1396 women) who attended the United States Military Academy between 1990 and 2003, each for a 4-year college career. Mean class size was 1042, with an average of 140 (13.4%) women and 902 (86.6%) men in each class. A total of 341 cadets had ACL injuries. Twelve cadets (10 men and 2 women) sustained bilateral ACL tears, for a total of 353 ACL injuries.[10]

A total of 165 meniscal tears were observed in 140 participants. A meniscal tear was observed in 39.6% (140/353) of cadets who sustained an ACL tear at arthroscopy (95% confidence interval [CI], 34.5%-45%). Of the 140 cadets who sustained meniscal tears, 68 had isolated medial meniscal tears, 47 had isolated lateral meniscal tears, and 25 had medial and lateral meniscal tears.

The cumulative incidence of concomitant isolated medial and lateral meniscal tears and the combined medial and lateral meniscal pathology were 19.3% (95% CI, 15.3%-23.8%), 13.3% (95% CI, 9.9%-17.3%), and 7.1% (95% CI, 4.6%-10.3%), respectively. The cumulative incidence of isolated medial meniscal tears was significantly higher (relative risk=1.45; 95% CI, 0.98%-2.14%; P=.05) when compared with lateral meniscal tears. Twenty-five knees had a combined tear of the medial and lateral meniscus, and 115 knees sustained isolated meniscal tears. The medial meniscus accounted for 56% (93/165) of the total number of meniscal tears, and the lateral meniscus for 44% (72/165). Inclusive of all tears, the lateral meniscus was repairable in 22% (16/72) of knees and the medial meniscus in 30% (28/93) of knees.

Of the 301 knees of men, 147 (47%) had meniscal injuries. Sixty-four (44%) of these tears were lateral and 83 (56%) were medial. Of the 147 meniscal tears, 38 (26%) repairs were performed: 14 (22%) lateral and 24 (29%) medial. Of the 51 knees of women, 18 (35%) were meniscal injuries: 8 (44%) lateral and 10 (56%) medial. Of these 18 meniscal tears, 6 (33%) repairs were performed: 2 (25%) lateral and 4 (40%) medial. The number and distribution of meniscal tears and repairs by sex can be seen in Table 1.

All patients with meniscal injuries were undergoing concomitant ACL reconstruction. Because of the success of meniscal repair when performed in conjunction with ACL reconstruction in young patients, every effort was made to perform repairs whenever possible. Unrepairable tears in the white–white zone were debrided as necessary.

A total of 352 knees with ACL tears underwent reconstruction at the United States Military Academy (1 of the 353 tears was treated nonoperatively). In the 136 knees that underwent acute ACL reconstruction (defined as surgical treatment <30 days after injury), 71 (52%) were meniscal tears for 60 participants. Of the 71 meniscal tears, 31 (44%) were lateral and 40 (56%) were medial. Thirty-three percent (20/60) of participants had isolated lateral tears, 48% (29/60) had isolated medial tears, and 18% (11/60) had combined tears.

In the 216 knees that received delayed ACL reconstruction, defined as surgical treatment >30 days after injury, 102 (41%) were meniscal tears for 89 participants. Of the total number of tears, 56% (57/102) were medial and 44% (45/102) were lateral. Of the patients who received delayed treatment, 30 (15%) had lateral meniscal tears, 44 (20%) had medial meniscal tears, and 13 (11%) had combined tears. No significant difference was found between acute vs delayed treatment and the incidence of meniscal tears.

Sixteen percent (5/31) of lateral tears and 33% (13/40) of medial tears were repaired acutely. In the delayed treatment group, 24% (11/45) of the lateral tears were repaired vs 26% (15/57) of the medial tears. No statistically significant differences in meniscal repairability were found based on time to surgery.

Compared with other sports, wrestling and volleyball had the highest incidence of concomitant meniscal tears at 77% and 125%, respectively (Table 2). Other sports, including football and soccer, did not differ significantly from the overall concomitant meniscal injury rate of 39.6% (range, 0%-64%).

Table 1

Incidence and Location of Meniscal Injury by Sex

Demographic	No. (%)				
	Total Meniscal Tears	Lateral Meniscal Tear	Medial Meniscal Tear	Lateral Meniscal Repair	Medial Meniscal Repair
All cadets (N=353)	165 (47)	72 (44)	93 (56)	16 (22)	28 (30)
Male (n=302)	147 (49)	64 (44)	83 (56)	14 (22)	24 (29)
Female (n=51)	18 (35)	8 (44)	10 (56)	2 (25)	4 (40)

A total of 123 ACL injuries occurred while athletes participated in sports at the club and intercollegiate level. Of these, 65 (53%) were meniscal tears: 29 (45%) lateral and 36 (55%) medial. Seven (24%) of the lateral menisci and 10 (28%) medial menisci were repaired. The incidence of meniscal injury by level of play and mechanism of injury is shown in Table 3.

A similar number of ACL injuries (n=124) occurred while students participated in intramural sports or sports in their free time. Fewer meniscal injuries (n=56, 45%) were sustained during this level of activity compared with the intercollegiate and club level. Of the 56 meniscal injuries, 27 (48%) were lateral and 29 (52%) were medial. Five (18.5%) lateral and 9 (31%) medial menisci were repaired in this group.

Table 2

Incidence of Meniscal Injury by Sport

Sport	No.		Incidence, %
	Meniscal Tears	ACL Injuries	
Wrestling	17	22	77
Soccer	12	26	46
Skiing	9	21	43
Rugby	23	46	50
Football	53	106	50
Basketball	15	34	44
Baseball	0	1	0
Gymnastics	6	15	40
Handball	7	11	64
Military-specific training[a]	18	41	44
Volleyball	5	4	125
Lacrosse	5	8	63

Abbreviation: ACL, anterior cruciate ligament.
[a]*Includes judo, obstacle course, parachute, and rabblerouser.*

A total of 222 ACL injuries occurred during participation in noncontact sports, with a total of 107 (48%) meniscal injuries: 49 (46%) lateral and 58 (54%) medial. Of the lateral injuries, 11 (22%) were repaired, whereas 19 (33%) of the medial injuries were repaired.

Ninety-five (27%) patients sustained ACL disruption while participating in contact sports. Of those patients, 44 (43%) sustained meniscal injuries. Nineteen (43%) were lateral, of which 5 (57%) were repaired. Twenty-five (57%) were medial, of which 8 (32%) were repaired.

Discussion

Ample literature regarding the occurrence of meniscal tears in the ACL-deficient knee, with >30 articles pub-

Table 3

Incidence of Meniscal Injury by Level of Play and Mechanism of Injury

	No. of Meniscal Tears (%)		
Level of Play/Mechanism	**Lateral**	**Medial**	**Total**
Club/intercollegiate (n=123)	29 (45)	36 (55)	65 (53)
Intramural/free time (n=124)	27 (48)	29 (52)	56 (45)
Noncontact (n=222)	49 (46)	58 (54)	107 (48)
Contact (n=95)	19 (43)	25 (57)	44 (46)

lished on the topic since 1980.[1,11] However, despite the large number of articles, many aspects of these combined knee injuries remain in question. In the current study, we analyzed prospective injury data from 10 consecutive United States Military Academy classes. We were able to determine the cumulative incidence of meniscal injury with concomitant ACL disruption. In addition, we were able to categorize meniscal injury based on laterality, repairability, time to surgery, sex, level of sport, and mechanism of injury.

Previous studies evaluating concomitant meniscal and ACL injuries were limited by small sample size, lack of demographic data, and a narrow longitudinal study period.[3,4,6,8,11-13] A major weakness of these previous studies is that the incidence of meniscal tears was based on the number of patients receiving ACL reconstruction and not on the number of ACL tears.[8,12] In our study, 353 ACL tears in 10,419 young athletes were found, and 352 underwent ACL reconstruction, removing selection bias. To our knowledge, we are the first to report the concomitant meniscal injury rate in a large population of prospectively followed ACL tears.

Concomitant meniscal tears occurred in 39.6% of participants who sustained ACL injuries. This finding is consistent with rates in the literature, ranging from 41% to 82%.[1-3,5,11] In the largest study to date on the location of concomitant meniscal tears with ACL injuries, the authors demonstrated nearly equivalent tear rates between medial and lateral menisci, with 53% of tears occurring medially and 46.9% occurring laterally, although the difference did not reach statistical significance.[12] Unfortunately, despite the large number of tears included (N=575), the study gives no demographic information about the patients other than time to surgery (78.3% with ⩽6 weeks and 26.7% with >6 weeks to surgery) and mean age (25.4 years). Similarly, we found that 56% of tears were medial and 44% were lateral, although this did not reach statistical significance. In the aforementioned study, the authors demonstrated that 75% of medial meniscal tears occurred in the peripheral posterior horn, reinforcing the theory of the medial meniscus acting as a secondary stabilizer in the ACL-deficient knee.[12]

Despite similar rates of overall meniscal injury, our study differs from previous studies when considering distribution of tears and chronicity of injury. Previous studies demonstrated that lateral meniscal tears occur more commonly in knees with acute ACL injuries, with an average distribution of 56% lateral and 46% medial.[1,5] In addition, previous studies have shown a higher incidence of overall meniscal injury in the chronically ACL-deficient injured knee.[7,8]

However, our data showed a nearly equivalent incidence of meniscal injury in acute and chronically injured knees. The incidence of medial meniscal injury was equivalent between acute and chronically injured knees, occurring in 56% of acute and 56% of chronically injured knees. In addition, medial meniscal tears are more common than lateral meniscal tears, regardless of chronicity.

Interestingly, the incidence of lateral meniscal tears was also equivalent in the acute and chronic injury periods (44%). Our definition of acute and chronic deserves repeat mention, as we used surgery within 30 days as our boundary for this distinction—a time point that is sooner than many patients at other institutions present for surgery. Our unique institutional health care system makes the generalizability of the time assessment difficult. We chose 30 days because 67% of our patients underwent reconstruction within 45 days and 93% within 120 days. Even when broken into quintiles, our time-to-surgery assessment showed no significant effect of delay resulting in greater meniscal pathology. However, this could be due to the majority of our patients undergoing early surgery.

It remains unclear whether female athletes have an increased tendency toward ACL tears.[1,9,10,13-16] In a study evaluating ACL injuries in men's and women's collegiate soccer and basketball programs over 5 years, the authors found a higher rate of ACL injuries in women compared with men and a distinctive difference in the rate of associated meniscal injury.[9] Our results trended toward an increased incidence of associated meniscal injury in men (47%) compared with women (35%), although this was not statistically significant. This reinforces the concept that the causes of ACL injury and associated meniscal injury in men and women are varied and multifactorial.

Bellabarba et al[1] concluded that the laterality of a menis-

cal tear can predict the likelihood of meniscal repair. The authors found that the percentage of repairable meniscal tears is higher for medial vs lateral tears. In our cohort, no statistical differences existed in the repairability of medial vs lateral tears overall, regardless of time to surgery, when comparing men and women and contact and noncontact injuries and when accounting for competition level. However, a trend was observed toward increased repairability of the medial meniscus overall, with a 30% repair rate, vs the lateral meniscus overall, with a 22% repair rate.

The current study has limitations that should be considered when interpreting the results. The primary purpose of the parent cohort study was to identify the incidence of ACL injuries in a large and physically active cohort.[10] The current study represents a subanalysis within the parent cohort to identify the incidence of meniscal injuries with concomitant ACL injuries. As a result, the study was powered based on the primary outcome of interest. Therefore, some of the stratified analyses presented in this article may be underpowered to make definitive conclusions, despite the large number of incident ACL injured cases and concomitant meniscal injuries in this cohort. Therefore, our results must be interpreted by the reader with some caution. Larger multicenter studies may be required to definitively answer some of these questions.

Another limitation is the population that was studied. Although the study population was young, physically active, and required to participate in organized sports every semester during the study period, it was also predominantly male, limiting the generalizability of these findings to similar populations.

Despite these limitations, the current study has several strengths, 1 of which is the number of meniscal tears (n=166) included. Although other studies have greater numbers,[12] they do not have the extensive patient- and injury-specific data presented here. This is important to consider because in the previous ACL study from this cohort, little difference was found in ACL tear rates between men and women. Sex differences were significant when specific sports and activities were compared.[10]

Because of the nature of the service academy and the process by which injuries are documented, we are confident that we identified all ACL injuries and did not underreport rates. Most importantly, 352 of 353 ACL injuries underwent ACL reconstruction, allowing us to identify all meniscal tears. Despite our large and well-documented cohort, our rates of concomitant meniscal injury based on laterality, level of sport, mechanism of injury, timing of treatment, and sex did not reach statistical significance.

In addition, given the rather specific, male-dominated cohort, it is difficult to state with any certainty whether our results are predictive of the more generic group of young athletes as a whole.

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